RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1906. [July.

NOTES ON SOME FOSSILS FROM THE HALORITES LIMESTONE OF THE BAMBANAG CLIFF (KUMAON), COLLECTED BY THE LATE DR. A. VON KRAFFT IN THE YEAR 1900. BY CARL DIENER, PH.D., *University of Vienna*. (With Plates 1 and 2.)

IN 1892 a Cephalopod-bearing horizon of upper Triassic age was discovered on the southern slope of the Bambanag range, towering above the Girthi valley, near Martoli E.G., by the expedition in which Griesbach, Middlemiss and myself took part. This horizon was traced by myself from Lauka and the Jandi Pass in Johar to the Shalshal Cliff in Painkhanda, but nowhere was a section found which for abundance of Cephalopoda could be compared with that of the Bambanag Cliff. The rich fauna was examined by E. v. Mojsisovics (Denkschr. Kais. Akad.d. Wissensch. Wien, Bd. LXIII, and Himálayan Fossils, Palæontologia Indica, Ser. XV, Vol. III, Pt. 1), who described 58 species belonging to the genera and sub-genera: *Halorites, Parajuvavites, Thetidites, Tibetites, Anatibetites, Paratibetites, Helictites, Dittmarites, Dionites, Steinmannites, Clionites, Sandlingites, Sirenites, Arcestes, Pinacoceras, Placites, Bambanagites, Clydonautilus, Paranautilus, Indonautilus, Orthoceras* and *Atractites.*

Halorites being one of the most characteristic elements of the fauna, the name Halorites limestone was assigned to this horizon. It was correlated with the lower noric (lacic) stage of the Hallstatt limestone by E. v. Mojsisovics, who did not, however, overlook the specific similarities of a small number of types to species of middle-noric (alaunic) age.

In 1900 the Bambanag Cliff was re-visited by the late Dr. A. von Krafft, who obtained from the Halorites beds collections which, although less rich than my own in 1892, are still very extensive. These have been entrusted to me for examination. The majority of the species are identical with forms described by E. v. Mojsisovics; they are included in the following list:—

Atractites sp. ind.
Orthoceras sp. ind. (cf. *campanile*, Mojs. ?).
Clydonautilus biangularis, Mojs.
Paranautilus bambanagensis, Mojs.
Halorites Sapphonis, Mojs.
Halorites procyon, Mojs.
,, *Alcaci*, Mojs.
Parajuvavites Stoliczkai, Mojs.
,, *buddhaicus*, Mojs.
,, *Jacquini*, Mojs.
,, *Feistmanteli*, Mojs.
,, *Sternbergi*, Mojs.
,, *Ludolfi*, Mojs.
,, *Blanfordi*, Mojs.
,, *Renardi*, Mojs.
Tibetites Ryalli, Mojs.
,, *Murchisoni*, Mojs.
Paratibetites Adolfi, Mojs.
,, *Bertrandi*, Mojs.
,, *angustisellatus*, Mojs.
Clionites Woodwardi, Mojs.
,, *Hughesii*, Mojs.
,, *Salteri*, Mojs.
Sandlingites Archibaldi, Mojs.
,, *Nicolai*, Mojs.
Dittmarites Hindei, Mojs.
Thetidites Huxleyi, Mojs.
Steinmannites clionitoides, Mojs.
,, *Noetlingi*, Mojs.
,, *undulatostriatus*, Mojs.
,, *Desiderii*, Mojs.
,, *Lubbocki*, Mojs.
Arcestes Leonardi, Mojs.

Pinacoceras parma, Mojs.
Placites Sakuntala, Mojs.
Bambanagites Dieneri, Mojs.

Besides the species included in this list a small number of new forms has been recognised, which will be described in the present memoir.

Genus **PINACOCERAS** Mojs.

PINACOCERAS METTERNICHII Hauer. Pl. I, fig. 2.

1846. *Ammonites Metternichii* F. v. Hauer *ex-parte*, Die Cephaloden des Salzkammergutes aus der Sammlung des Fuersten von Metternich, Wien, W. Branmuller, p. 1, Taf. IV, fig. 4.

1873. *Pinacoceras Metternichii* E. v. Mojsisovics, Die Cephaloden der Hallstätter Kalke, Abhandl. K. K. Geol. Reichsanst, VI-1, p. 60, Taf. XXVI, fig. 1.

1902. *Pinacoceras Metternichii* E. v. Mojsisovics, *ibidem*, Supplement, p. 295, Taf. XIX, fig. 1.

1906. *Pinacoceras Metternichii* Diener, The fauna of the Tropites limestone, Palæontologia Indica, Ser. XV, Himálayan Foss., Vol. V, Pt. 1, Pl. XIII, fig. 1.

A medium-sized specimen of *Pinacoceras* consisting of air-chambers only, agrees in the details of its sutural line with *Pinacoceras Metternichii* Hauer, not with *P. parma* Mojs.

Pinacoceras Metternichii and *P. parma* are two very nearly allied species, which can only be distinguished by a subordinate difference in their sutural lines. In *P. parma* the five adventitious saddles are of dimeroid shape, whereas in *P. Metternichii* the saddle preceding the principal lateral one is pyramidal, the inner of the two culminating branches being much more strongly developed and higher than the outer one and being shifted towards the centre of the apex of the saddle. In this character my specimen agrees exactly with F. v. Hauer's type-specimen of *Pinacoceras Metternichii* from the Steinbergkogel near Hallstatt.

There are three dimeroid adventitious saddles, following the first adventitious saddle, whose lateral branches are arranged symmetrically, four pyramidal saddles—the fifth, innermost adventitious saddle and the three main saddles—and ten dimeroid auxiliary saddles.

The first or outermost adventitious saddle is not provided with a secondary external branch, as in the variety from the Tropites lime stone of Kalapani, but its ramifications are arranged symmetrically.

as in the typical form from the Hallstatt limestone. The adventitious elements of the sutural line slope more steeply from the periphery of the shell to the first main saddle than in Hauer's type, but less so than in the Himálayan example from the Tropites limestone.

The measurements of this incomplete but fairly well-preserved specimen are as follow:—

Diameter of the shell	. . . . . .	140 mm.
„ „ umbilicus	. . . . .	15 „
Height of the last volution	above the umbilical suture . .	77 „
	„ „ preceding whorl . .	54 „
Thickness of the last volution	. . . . .	17 „

Pinacoceras Metternichii must now be added to the list of species common to the Halorites limestone, the Tropites limestone of Byans and the Alpine Hallstatt beds.

PINACOCERAS POSTPARMA Mojs. Pl. 1, fig. 1.

1873. *Pinacoceras postparma* E. v. Mojsisovics, Die Cephalopoden der Hallstätter Kalke : Abhandl. K. K. Geol. Reichsanst, VI-1, p. 61, Taf. XXVI, fig. 4.

1902. *P. postparma* E. v. Mojsisovics, *ibidem*, Supplement, p. 295.

A medium-sized specimen of *Pinacoceras* consisting of air-chambers only, agrees exactly with this remarkable species from the alaunic (middle noric) sub-stage of the Hallstatt limestone. The most important character of *P. postparma* is the shape of the fifth adventitious lobe and adjoining saddles. As in the type-specimen from Hallstatt four adventitious lobes are bi-partite at their base and separated by dimeroid saddles. But the fifth adventitious lobe is shorter and narrower and terminates in a median point. The two bordering saddles stand very close to each other. Although distinctly dimeroid like, the rest of the adventitious saddles, they might easily be mistaken for a single adventitious saddle, whose branches divide near the very base of the stem.

In its external shape *Pinacoceras postparma* agrees exactly with *P. parma* and *P. Metternichii.*

Dimensions.

Diameter of the shell	. . . .	136 mm.
„ „ „ umbilicus	. . . . . .	12 „
Height of the last volution	above the umbilical suture . .	81 „
	„ „ preceding whorl . .	58 „
Thickness of the last volution	. . . .	18 „

Pinacoceras postparma must be added to the number of forms in the Halorites limestone exhibiting specific affinites to Alpine species of alaunic age, such as *Clydonautilus biangularis* and *Sirenites elegans.*

Genus: HALORITES Mojs.

HALORITES TROTTERI, nov. sp. Pl. 2, fig. 4.

This is a species of *Halorites* belonging to the group of *acatenati*, as do all Himálayan representatives of this genus hitherto known. The chambered portions of its shell agree almost entirely with *Halorites Sapphonis* Mojs. (Palæontol. Indica, ser. XV, Himál. Foss., Vol. III, Pt. 1, p. 13, Pl. IV, figs. 1—4). Their ornamentation consists of numerous zig-zag bent ribs, bifurcating both on the lower half of the lateral parts and near the siphonal margin.

The body-chamber differs in its sculpture considerably from *H. Sapphonis* by the absence of any marginal knobs and by the gradual weakening of the ribs. A deep constriction, which is situated nearly one entire volution in front of the last sutural line, marks the immediate vicinity of the peristome, of which, however, only traces have been preserved.

The egression of the umbilicus is also considerably inferior to that in *H. Sapphonis.* Where the shell has been preserved, the umbilicus is entirely closed by a callosity.

The modifications in the shape of the body-chamber are rather insignificant. The siphonal part, which is broadly rounded near the beginning of the last volution, becomes more compressed in the middle of the body-chamber whorl, whereas towards the mouth there occur again a slight widening of the external region and a corresponding inflation of the lateral parts.

Dimensions.

Diameter of the shell	68·5 mm.
„ „ „ umbilicus	0 „
Height of the last volution { above the umbilical suture . .	37 „
Height of the last volution { „ „ preceding whorl . .	15 „
Thickness of the last volution	29 „

Sutures.—Agreeing in their details with those of *Halorites Sapphonis.*

HALORITES ALTERNANS nov. sp. Pl. 1, fig. 3.

This species, represented only by the figured specimen, is to be regarded as a form closely allied to *Halorites Alcaci* Mojs. (l. c. p 17, Pl. III, fig. 3). It is distinguished from this species and from all other Indian *Halorites* by two characters of importance.

The first character of importance is the absence of any egression of the umbilicus. The second is the sharp separation of the sculpture in the anterior and posterior portions of the last volution. Near its beginning the last volution, corresponding entirely to the body-chamber, is considerably inflated and covered by very numerous and delicate, sharp ribs, which cross the broadly rounded siphonal area with many bifurcations. These delicate and densely crowded ribs are suddenly replaced by flattened, irregularly bending folds, which stand more widely apart and are elevated into marginal knobs.

The sharp boundary between those two patterns of ornamentation corresponds to the region of the body-chamber, where the compression of the whorl begins. On the anterior portion of the body-chamber a considerable weakening of the sculpture is coincident with the increase of the inflation in the apertural region.

Dimensions.

Diameter of the shell	. . . .	40 mm.
" " " umbilicus	. . . . . .	0 "
Height of the last volution	. . . . . .	22 "
Thickness of the last volution	at the point of greatest inflation .	20 "
	" " " " " compression	16 "

Sutures.—Not known in detail.

MARTOLITES nov. gen.

To this genus belong evolute shells with numerous whorls and a widely open umbilicus recalling in their shape *Japonites* or *Gymnites*. The sculpture is interrupted along the narrow external part, as in *Florianites* or *Danubites*. It consists of simple ribs, of which two or three originate from umbilical tubercles. To this plicate ornamentation paulostome-furrows are added, as in *Cycloceltites* Mojs.

The sutures are very simple. It is merely a matter of convenience, whether one regards the small umbilical saddle as second lateral or as auxiliary saddle, the projection of the periphery of the preceding volution just touching the broad lobe which follows the principal lateral saddle.

It is rather difficult to assign to this genus its proper systematic position. I have not succeeded in finding out the exact length of the body-chamber, the sutural line being only accessible to examination at one single place in the penultimate whorl of my largest specimen of *Martolites Kraffti*. Thus whether *Martolites* belongs to the *Tropitidæ* or to the *Ceratitidæ* cannot be decided on the strength of the main character on which the separation of those two groups of Triassic *Ammonea trachyostraca* has been based by E. v. Mojsisovics. My personal opinion is, that *Martolites* should be placed in the sub-family *Celtitinæ*, near *Celtites* Mojs. The affinity of *Martolites* to *Celtites* appears to me to be stronger than to any other Alpine genus of upper Triassic ammonites. An inspection of the illustration of *Celtites Neumayri* as given by E. v. Mojsisovics (Abhandl. K. K. Geol. Reichsanst. VI-2, Taf. CC., fig. 6) and of *Cycloceltites annulatus* Mojs. (*ibid.* Taf. CXXII, figs. 8—14) will convince the reader of the remarkable similarity of the two genera in their external shape and involution. With *Cycloceltites* my new genus agrees in the combination of normal ribs with paulostome-ribs and furrows. A difference is, however, marked by the presence of umbilical tubercles and by interruption of the sculpture along the siphonal part. The latter feature is noticed in the group of *Celtites multispirati*, but not in *Cycloceltites*.

Martolites is so far only known from the Halorites limestone of the Himálayas, where it is represented by a single species, *M. Kraffti*.

MARTOLITES KRAFFTI nov. sp. Pl. 2, figs. 1, 2, 3.

Of the three specimens figured the largest, illustrated in fig. 1, may stand as the type of this species. It possesses an obliquely elliptical outline, which is, however, acquired only in later stages of growth. The inner nucleus is of normal shape and agrees exactly with the smaller example illustrated in fig. 3. The elliptical outline of the full-grown specimen is confined to the last volution and is probably caused by an acceleration of growth in front of the beginning of the last whorl and in front of the anterior half of it.

The whorls of the inner nucleus are strongly inflated and thicker than high, but in the cross-section of the last whorl the width is inferior to the height. The transverse section is cordiform, the sides converging into a narrowly rounded siphonal part. The whorls overlap each other scarcely to the fourth part of their height. Thus a wide and shallow umbilicus is left open.

The ornamentation consists of very numerous straight and sharp ribs, which are turned forward but do not cross the siphonal part, which remains smooth. In the inner nucleus single ribs occur occasionally, but are rare. Most of the ribs rise in pairs from the umbilical edge, which separates the flat lateral parts from a steep but very low umbilical wall. Bifurcation of the ribs outside the umbilical region is also frequently noticed. In the inner nuclei the points of bifurcation along the umbilical edge are not marked by tubercles. It is only in the last volution of the two larger specimens illustrated, that umbilical tubercles play an important part in the ornamentation of the shell. In the meantime the ribs become more densely crowded and more than two often rise from a single umbilical tubercle.

The second element of sculpture is paulostome-furrows, which are as a rule connected with strong paulostome-ribs They appear at an earlier stage of development than the umbilical tubercles. In the small specimen illustrated in fig. 3 a deep paulostome-furrow is noticed corresponding to a diameter of the shell of 13 mm. It is directed forward more noticeably than the lateral ribs and is accompanied by a sharp paulostome-rib, cutting off two adjoining ribs and thus forming with them a sort of chain-rib, recalling the chain ribs in the group of *Anatomites scissi.*

In the last volution of my type-specimen two deep paulostome-furrows are noticed. But the paulostome-ribs preceding them do not cut off any adjoining ribs, deviating but slightly from their direction. From the normal ribs the paulostome ribs differ not only in their greater strength but also by crossing the external part without any interruption.

Dimensions.

	Fig. 1.	Fig. 3.
Diameter of the shell	37 mm.	18 mm.
Height } of the last volution	12 „	6·5 „
Thickness } of the last volution	9 „	7 „
Diameter of the umbilicus	16 „	6·5 „
Height } of the volution at the place of its greatest aplanation	10 „	
Thickness } of the volution at the place of its greatest aplanation	8·5 „	
Corresponding diameter of the shell	28 „	
„ „ „ umbilicus	13 „	

Sutures.—There is only a single place near the beginning of the penultimate whorl, where the sutural line of two air-chambers is accessible for examination. The siphonal lobe is deep, bicuspidate and divided by a high siphonal prominence. Siphonal saddle high and elongated, with its apex shifted towards the external part. Lateral lobe faintly serrated at its base, but serration visible only by means of a magnifying glass. Lateral saddle shorter than the siphonal saddle and followed by a broad, faintly serrated lobe, which might be termed either lateral or auxiliary with equal reason. The inner margin of the small adjoining saddle is touched by the umbilical suture.

Genus **JUVAVITES** Mojs.

Sub-genus *ANATOMITES* Mojsisovics.

ANATOMITES sp. ind. Pl. 1, fig. 4.

The figured specimen is the chambered nucleus of a large-sized example, which in its dimensions can scarcely have been inferior to *Anatomites Camilli* Mojsisovics (Cephalopoden der Hallstätter Kalke, Abhandl. K. K. Geol. Reichsanst, VI-2, p. 103, Taf. XCI, fig. 3), to which it exhibits a distant resemblance. It deserves special mention, since the sub-genus *Anatomites* is chiefly restricted to beds of carnic age and is very rare in the noric stage of the Hallstatt limestone. The present nucleus belongs to the group of *Anatomites scissi*. On account of its incompleteness it is preferable to refrain from the imposition of a new specific name.

There are two paulostome-furrows present in the last volution, both of them being accompanied by strong ribs on either side. The lateral ribs, which are broad, irregularly bent, and frequently dichotomous, meet alternately along the middle line of the siphonal part, where the sculpture is interrupted.

The direction of the paulostome-furrows is inclined obliquely forward. The bundle of ribs preceding the last paulostome has a chain-like appearance, but in the rib preceding the first paulostome this is not the case.

Dimensions.

Diameter of the shell	24 mm.
" " umbilicus	2 "
Height } of the last volution	13 "
Thickness } of the last volution	12·5 "

NOTES ON AN UPPER-TRIASSIC FAUNA FROM THE PISHIN DISTRICT, BALUCHISTAN, COLLECTED BY E. VREDENBURG IN THE YEAR 1901. BY C. DIENER, PH.D., *University of Vienna.* (With Plates 3 and 4.)

IN Volume XXXI (pp. 162—166) of the *Records, Geological Survey of India*, a very interesting paper on the Triassic rocks of Baluchistan was published by E. Vredenburg. His survey in 1901 disclosed a large development of Triassic beds in the highlands of the Pishin district, Baluchistan, south of the Upper Zhob Valley. He found the Khojak shales of Tertiary age in this district to be confined to narrow synclines and underlain by a great mass of shales, lithologically identical with the Khojak shales, but with Triassic fossils uniformly distributed throughout them.

As the chief leading fossil of the Triassic shales a species of *Monotis* is quoted, which Vredenburg considered as closely allied to, or identical with, *Monotis salinaria* Schloth. A species of *Halorites* was discovered *in situ* on the road from Pishin to Ziarat. It has been illustrated by Vredenburg on Pl. 17, accompanying his memoir, and referred to the group of *catenati continui*. From the presence of this species and of *Monotis salinaria* he concluded that the *Monotis*-bearing shales of Baluchistan ought to be correlated with the *Monotis*-beds of Spiti or with the alaunic (middle noric) sub-stage of the Alpine Trias and that they were slightly younger in age than the Halorites limestone of the Central Himálayas, where the genus *Halorites* is represented by acatenate types only.

All the fossils collected in the Triassic rocks of Baluchistan by Vredenburg were entrusted to me for examination. The fauna is very scanty. Impressions of *Monotis* are abundant, but all the rest of the fossils are represented by fragmentary specimens. Their state of preservation is far from being satisfactory, only very few admitting of a specific determination. All the Cephalopoda are casts in a calcareous shale or in a very hard lydian-stone without any trace of their shelly substance. They probably belong to new species, but only one among them has been considered worthy of a new specific designation.

DESCRIPTION OF FOSSILS.

MONOTIS SALINARIA Schloth. Pl. 3, figs. 1, 2, 3.

1820. ***Pectinites salinarius*** v. Schlotheim, Petrefactenkunde, p. 230.

1830. ***Monotis salinaria*** Bronn, Uber die Muschelversteinerungen des sueddeutschen Steinsalzgebirges, welche bisher unter dem Namen Pectinites salinarius zusammenbegriffen wurden. Neues Jahrb. f. Min., etc. Bd. I, p. 279, Taf. IV, fig. 1.

1894. ***Monotis salinaria*** Teller, in E. Suess, Beitraege zur Stratigraphie Centralasiens, Denkschr. Kais. Akad. d. Wiss, LXI, p. 460.

1900. ***Monotis salinaria*** A. v. Krafit, General Report, Geol. Surv. of India, for 1899—1900, p. 222.

1904 ***Monotis cf. salinaria*** Vredenburg, Records, Geol. Surv. of India, Vol. XXXI, p. 160, Pl. 17, fig. 1.

Impressions of shells belonging to this species are very richly represented in Vredenburg's collections, sometimes coating the entire surface of slabs of shale. The majority, however, are fragmentary and examples in which the apical region has been preserved are few in number. In some slabs fragments of the shelly substance have been found adhering to the impressions.

On the slabs of rock, illustrated in Pl. 3, fig. 1, three impressions of left valves are almost entirely preserved. They distinctly show the radiating ornamentation, the straight hinge-line with low sub-central beaks and an edentulous hinge, the rounded anterior margin and a short, obliquely truncated posterior wing. Traces of the adductor scar are very indistinctly developed. The only impression of a right valve on this slab is, unfortunately incomplete, the anterior region near the beak having been destroyed. It is consequently impossible to arrive at an exact generic determination of the shells in question.

Their relationship to two genera, ***Monotis*** Bronn and ***Pseudomonotis*** Beyr., must be taken into consideration. Some species of ***Pseudomonotis*** agree so closely with ***Monotis salinaria*** in their external characters, that an exact determination of left valves is utterly impossible. The only difference of generic importance, which justifies a separation of ***Monotis*** and ***Pseudomonotis***, is the presence of a byssal notch in the minute anterior wing of the right valve of the latter genus.

In the majority of species of ***Pseudomonotis*** the shell is inequivalve, the right valve being the smaller. An inspection of the impressions illustrated in fig. 1 shows that the shells from the Pishin district are equivalve, but an exact determination cannot be based on this character alone, as it is also observed in some groups of Triassic *Pseudomonotis, viz.*, in the Pacific groups of *Ps. ochotica* or *Ps. Richmondiana.*[1]

Impressions of right valves are comparatively rare in Vredenburg's materials. I have succeeded in making plaster casts of two impressions (figs. 2, 3), in which the hinge-margin has been sufficiently well preserved to ascertain the absence of any anterior wing or byssal notch in front of the apex. Nor has a trace of such characters been noticed in any of the casts of right valves entrusted to me for examination. It is especially the example illustrated in fig. 3, which agrees with *Monotis salinaria* not only in the absence of any anterior wing, but also in the outlines of the anterior margin, which unites with the hinge-line in a sharply rounded-off angle.

Thus the identification of the species from Baluchistan with *Monotis salinaria*, as suggested by Vredenburg, has been proved to be entirely correct. There can be no doubt that the Baluchistan shells belong to the Alpine type of *Monotis salinaria* and not to the Pacific type of *Pseudomonotis ochotica*. In this respect they agree with the type described from the Pamir by Teller which had been collected N. E. of Aktash, 4 miles W. of the Nizatash pass by Stoliczka, and with the Himálayan type from Spiti, collected by Hayden and A. v. Krafft. My examination of the Himálayan specimens fully confirms their identification with *Monotis salinaria* by A. v. Krafft.

Monotis salinaria is extremely variable in its dimensions and outlines, but its variations have never been studied in detail. It is an astonishing fact that the first reliable description of this leading fossil of the noric Hallstatt limestone published by Bronn in 1830 is still the only one existing. For the moment there is no reason for introducing a new specific denomination for the Indian types of *Monotis salinaria.*

Dimensions.

	Fig. 1. (left valve.)	Fig. 3. (right valve.)
Entire length of the shell	33 mm.	34 mm.
„ breadth „ „	28 „	25 „
Length of the hinge-line	16 „	17 „
Distance of the apex from the anterior margin	9 „	11 „
Distance of the apex „ „ posterior „ .	24 „	23 „

[1]*Vide*: *T. Teller*, Die Pelecypodenfauna von Werchojansk in Ostsibirien; in *E. v. Mojsisovics*, Arktische Traisfaunen, Mém. Acad. Imper. des Sciences de St. Petersburg, VII sér., T. XXXIII, No. 6, 1886, pp. 105—124.

The thickness of the valves cannot be measured, the impressions having been considerably crushed in the soft shales.

Locality.—N.E. of Kudin, underlying northern branch of the Tertiary syncline (Nos. 310 and 370); about 1 mile S.E. of Muhammed Azim, Lat. 30° 38′, Long. 67° 36′ (No. 372); summit 8,644 feet, about 3 miles S.W. of Kudin (No. 245); E. of Kudin (No. 306).

HALORITES nov. sp. ind. aff. SUBCATENATO Mojs. Pl. 4, fig. 1.

1904. *Halorites sp. ind.* Vredenburg, Records Geol. Survey of India, Vol. XXXI, p. 162, Pl. 17, fig. 2.

As has been stated by Vredenburg, this specimen is the only Indian representative of the group of *catenati continui.* It is entirely chambered, no fragment of the body-chamber having been preserved. I consequently prefer to abstain from a direct identification with any European species and from the introduction of a new specific name.

Of Alpine species of the genus *Halorites* it is probably *H. subcatenatus* E. v. Mojsisovics (Die Cephalopoden der Hallstätter Kalke, Abhandl. K. K. Geol. Reichsanst. VI-2, p. 18, Taf. LXXV, fig. 1, XCVIII, fig. 1), to which the Indian example is most nearly allied. It is the one with which it agrees best in the proportion of height and width of chambered inner nuclei. There is also an almost complete agreement in the character of the ribs and of the pearl-shaped tubercles. I have been able to convince myself of this fact by a personal comparison of my example with the type-specimens in the Museum of the K. K. Geologische Reichsanstalt in Vienna, illustrated by E. v. Mojsisovics.

The umbilicus is partly exposed as a deep and comparatively broad funnel. The illustrations of my type-specimen in figs. 1*a* and 1*b*, however, show a well-marked difference between the two sides of the cast. The exact dimensions of the umbilicus are therefore not known. Nor is it possible to suggest to what extent it may have been closed by a thickening or callosity of the shelly substance:—

Dimensions.

Diameter of the shell	50 mm.
" " " umbilicus	2 "
Height } of the last volution . . . {	about 34 "
Thickness } of the last volution . . . {	47 "

Sutures.—The sutural line is not known to me in detail. The contrast between the high, dolichophyllic main-saddles and the faintly developed auxiliary series, forming one broad, strongly serrated umbilical lobe, is very remarkable.

Locality.—About one mile S.E. of Muhammed Azim, Lat. 30° 38′, Long. 67° 36′ (No. 372).

Remarks.—*Halorites sp. ind. cf. ferox* v. Mojsisovics (l. c. p. 25, Taf. LXXIV, fig. 3) from the red Hallstatt marble of the Sommeraukogel (Salzkammergut) is also similar to our specimen but of smaller dimensions. The two species agree in the considerable number of pearl-shaped tubercles. Nevertheless the affinity of the present species to the group of *Halorites ferox* is more distant than to *H. subcatenatus*, because in *H. ferox* the chambered nuclei never reach the size of our Indian type.

DITTMARITES *an* DISTICHITES sp. ind. (?). Pl. 3, fig. 4.

The figured specimen is the fragment of a body-chamber, with a high-mouthed, elliptical cross-section and with two external keels, separated by a rounded median furrow and accompanied by deep lateral furrows on either side. The lateral parts are covered by very numerous and sharp, falciform ribs, which frequently dichotomise in the middle of the height. Umbilical tubercles are entirely absent. The complete specimen must have attained considerable dimensions and was provided with slowly increasing whorls, leaving open a wide umbilicus.

There are two genera of upper-Triassic ammonites, to which the present fragment might be compared. In my memoir on the fauna of the Tropites limestone (Palæontologia Indica, ser. XV, Himálayan Foss., Vol. V, Pt. 1) a species of *Dittmarites*—*D. Rawlinsoni* Diener—has been illustrated on Pl. VII, fig. 4, which in shape and ornamentation bears a close resemblance to our specimen in question. The second genus, which might put in a claim for comparison with nearly equal reason, is *Distichites* Mojs. *Distichites Younghusbandi* Diener (l. c. Pl. II, fig. 1,) although differing by its less densely crowded ribs, is certainly nearly allied, so far as we may judge from its general shape and sculpture. There is a still closer affinity to an undescribed form from the Monotis beds of Spiti, mentioned by A. v. Krafft in his preliminary report on the Mesozoic rocks of Spiti (General Report, Geol. Surv. of India for 1899-1900, p. 223). This species, which will be described in pt. 3 of Vol. V of the Himálayan Fossils, belongs to the group of *Distichites compressi.*

The characters of distinction between *Dittmarites* and *Distichites* not being accessible to observation in the present fragment, its generic determination must necessarily remain uncertain.

Dimensions.—Not measurable.

Locality.—3½ miles S. of Chinján, not *in situ* (No. 292).

CELTITES sp. ind. (*sectio* ACUTEPLICATI). Pl. 4 fig. 3.

This species represented by a single, imperfectly preserved example only, is of larger size than any of the congeneric forms from the Hallstatt limestone. It is distinguished by slowly increasing whorls, which overlap each other only to a very small extent, and by a wide umbilicus. The transverse section is square with rounded-off edges and moderately arched lateral parts. There is no distinctly defined umbilical margin developed. The numerous, simple, radiating ribs are sharp and interrupted along the median line of the siphonal part. No traces of parabolic ears as in the group of *annulati* (*Cycloceras*) or paulostome-furrows have been noticed. The number of coils is smaller than in the section of *multispirati.* The specimen is of larger dimensions than any of the Alpine dwarf-species of the section of *acuteplicati.*

Dimensions.

Diameter of the shell	. . . . . .	55 mm.
" " " umbilicus	. . . . .	26 "
Height } of the last volution	. . about	16 "
Thickness } of the last volution	. . about	13 "

Sutures.—Not known.

Remarks.—Although two important characters—the length of the body-chamber and the sutures—are unknown to me, there is a great probability of the correctness of assigning this species to the genus *Celtites.* I cannot find any other Triassic genus of *Ammonea trachyostraca,* to which it might be compared more advantageously, although its large size somewhat puzzles me. Had the specimen not been collected in an area of undoubted upper-Triassic age, the possibility of its belonging to *Danubites* or *Florianites* should certainly have been taken into consideration.

An identification with *Choristoceras* must be excluded. In a specimen of a *Choristoceras* of similar dimensions the umbilical suture of the last volution could no longer retain its normal spiral, as it does in the present example. Nor has any trace of external spines been noticed.

Locality.—Twelve miles S. of Hindu Bágh, not *in situ* (No. 373).

PARATIBETITES sp. ind. aff. TORNQUISTI Mojs. Pl. 4, fig. 4.

This is the fragment of a body-chamber of *Paratibetites* Mojs., recalling *Paratibetites Tornquisti* v. Mojsisovics (Palæontologia Indica, ser. XV., Himálayan Foss., Vol. III, Pt. 1, p. 87, Pl. XVI, fig. 5) from the Halorites limestone of the Himálayas.

The border-line of the aperture probably coincides with the actual peristome. The cross-section is helmet-shaped and distinguished by the three-edged termination of the siphonal part. This tripartite character of the siphonal side is more distinctly marked than in *Paratibetites Tornquisti*. The most important difference between the present species and *P. Tornquisti* is the presence of a strongly marked sculpture, consisting of falciform ribs, which are few in number and elevated into obtuse knobs in the umbilical region.

Dimensions.

Diameter of the shell	about	95 mm.
" " " umbilicus	"	8 "
Height } of the last volution . . .	"	50 "
Thickness } of the last volution . . .	"	30 "

Locality.—N.E. of Kudin, underlying northern branch of Tertiary syncline, not *in situ* (No. 310).

RHACOPHYLLITES VREDENBURGI nov. sp. Pl. 4, fig. 2.

This species, represented by a fairly well preserved specimen, is interesting on account of its shape, which is intermediate between the genera *Rhacophyllites* Zittel and *Phylloceras* Suess.

All Triassic species of *Rhacophyllites* hitherto known are distinguished from the geologically younger *Phylloceras* at a glance by their wider umbilicus. In the present species the umbilicus is considerably smaller than in any Triassic species of *Rhacophyllites*, although wider than in typical forms of *Phylloceras*. The umbilicus is surrounded by a high and steep wall, whose slope becomes less steep only in the anterior portion of the body-chamber. This wall is separated from the lateral parts by an obtusely rounded umbilical edge. From the siphonal part the flanks are also limited-off sharply by a marginal edge, which is very steeply rounded. Both the lateral and siphonal parts are nearly flat, thus imparting to the cross-section a rectangular outline with truncated angles.

The only traces of ornamentation on the cast are indistinct lines of growth, which are faintly developed in the vicinity of the aperture.

A little more than one half of the last volution belongs to the body-chamber.

Dimensions

Diameter of the shell	52	mm.
" " " umbilicus	7	"
Height of the last volution { above the umbilical suture	28·5	"
Height of the last volution { " " preceding whorl	17·5	"
Thickness of the last volution	18	"

Sutures.—The sutural line, as far as it is known to me, agrees with the sutures of *Rhacophyllites*, not of *Phhylloceras*. Only the main saddles are diphyllic, whereas the auxiliary saddles are all provided with monophyllic terminations. In the oblique position of the diphyllic siphonal saddle and in the presence of a short siphonal lobe the present species agrees with *Rhacophyllites Zitteli* Mojsisovics (Cephalopoden der Hallstätter Kalke, Abhandl. K. K Geol. Reichsanst., VI-1, Supplemented, p. 318, Taf. XVII, figs. 3, 4). The lateral saddles are not known in detail. The principal lateral lobe is strongly incised. Three auxiliary lobes and two saddles stand outside the umbilical suture.

Locality.—Twelve miles S. of Hindu Bágh (No. 373).

CONCLUDING REMARKS.

The examination of the fossils from the Pishin district collected by Vredenburg in 1901 fully confirms the views expressed by that author in his preliminary report.

The scanty fauna consists of the following forms:—

Monotis salinaria Schloth.
Halorites sp. ind. aff. *subcatenato* Mojs.
Celtites sp. ind. (group of *acuteplicati* ?)
Paratibetites sp. ind. ex. aff. *Tornquisti* Mojs.
Dittmarites an *Distichites* ? sp. ind.
Rhacophyllites Vredenburgi nov. sp.

Of these species only *Monotis salinaria* and *Halorites sp. ind. aff. subcatenato* were obtained at the actual spot where they had weathered out of the shales. All the rest of the specimens were picked up amongst transported boulders from the beds of the rivers that traverse the Triassic hills. Nevertheless their occurrence in the Triassic beds cannot be doubted. To this list must be added the specimen of *Didymites* which was collected in the Zhob district (Mazarghan river) by Griesbach and described as *Didymites afghanicus* by E. v. Mojsisovics (Himálayan Foss. l. c., Vol. III, Pt. 1, pp. 44, 144, Pl. XX, fig. 9).

The fossils enumerated above are of very different stratigraphical value. The specimens described as *Celtites sp. ind.* (?) and *Distichites an Dittmarites* (?) *sp. ind.* are too imperfectly preserved to afford any clue as to the age of the strata in which they occur. *Rhacophyllites Vredenburgi* is an isolated type among the representatives of this genus, which ranges from the middle carnic (julic) sub-stage of the upper Trias into beds of Jurassic age. *Paratibetites* is a sub-genus characteristic of the Halorites limestone of lower noric age, but has also been found associated with noric elements in the fauna of the *Tropites*-limestone of Byans. The group of *Halorites catenati continui* is represented in all sub-stages of the noric stage of the Alpine Hallstatt limestone, but chiefly in the alaunic sub-stage. In the Halorites limestone of the Himálayas the genus is only represented by acatenate forms. *Didymites* is regarded as one of the chief leading genera of the alaunic sub-stage. It must, however, be borne in mind that it occurs in large numbers in the *Tropites*-limestone of Byans and that in a fossiliferous bed of the Hallstatt limestone of Hallein *Didymites tectus* Mojs. has been noticed by Schlosser[1] associated with *Jovites dacus* Mojs. and with a few other ammonites of upper-carnic age. The main layer of *Monotis salinaria* in Europe is certainly the Hallstatt limestone of noric age. It is chiefly associated with types of the upper noric (sevatic) sub-stage. That it is, however, not restricted to the noric stage, has been proved by G. v. Bukowski, who collected large numbers of this shell in the carnic Hallstatt limestone of Spizza (Verhandl. K. K. Geol. Reichsanst., 1896, p. 105). My personal examination of Bukowski's specimens has convinced me of the correctness of Bittner's statement, that they cannot be separated

[1] *M. Schlosser*: Das Triasgebiet von Hallein, Zeitschr. Deutsche Geol. Ges., 1898, p. 365.

from *M. salinaria* Schloth. In the Himálayas of Spiti the species has been discovered by A. v. Krafft and Hayden in beds of noric age, which are geologically younger than the Halorites limestone of the Bambanag Cliff.

So far as it goes, the evidence afforded by the scanty fauna collected by Vredenburg is in harmony with a correlation of the Triassic beds of the Pishin district with the noric stage of the Alpine upper Trias. It is not possible to come to a more exact determination of their age, although there is good reason for their correlation with the *Monotis*-bearing horizon of the Himálayas, which is certainly not older than the middle noric (alaunic) sub-stage.

EXPLANATION OF PLATES.

PLATE 3.

Fig. 1. *Monotis salinaria* Schloth, (No. 372) 1 mile S.E. of Muhammed Azim.

" 2. *Monotis salinaria* Schloth. (No. 310). Plaster cast of a right valve. N.E. of Kudin, underlying northern branch of Tertiary syncline.

" 3. *Monotis salinaria* Schloth. (No. 295.) Plaster cast of a right valve. Summit 8,644 feet, about 3 miles S.W. of Kudin.

" 4*a*, *b*. *Distichites* an *Dittmarites* sp. ind. (?) 3½ miles S. of Chinjan (not *in situ*).

PLATE 4.

Fig. 1*a*, *b*, *c*. *Halorites* sp. ind. aff. *subcatenato* Mojs. 1 mile S.E. of Muhammed Azim.

" 2*a*, *b*, *c*, *d*. *Rhacophyllites Vredenburgi* Diener. 12 miles S. of Hindu Bágh (not *in situ*).

" 3 *Celtites* sp. ind. (?) 12 miles S. of Hindu Bágh (not *in situ*).

" 4*a*, *b*. *Paratibetites* sp. ind. aff. *Tornquisti* Mojs. N.E. of Kudin, underlying northern branch of Tertiary syncline (not *in situ*).

NOTES ON THE GEOLOGY OF A PORTION OF BHUTAN.

BY GUY E. PILGRIM, B.SC., *Deputy Superintendent, Geological Survey of India.* (With Plates 5 and 6.)

Introduction.

IN the early portion of this year I was afforded an opportunity of accompanying Mr. J. Claude White, the Political Officer for Sikkim, some distance into the interior of Bhutan, and also of examining portions of the foot-hills on the Bhutanese frontier, which hitherto have been geologically unknown. Owing to the rapidity of my journey and the densely wooded character of the hills, it was impossible for me to attempt any detailed geological survey of the country. Still, such observations as I was able to make appear to possess some interest in view of our scanty knowledge of the geology of the eastern portions of the Sub-Himálayan foot-hills.

Previous work on the geology of the Eastern Sub-Himalayas.

Of the sources of our information on their geology, Mr. F. R. Mallet's[1] important work in Darjeeling and the Baxa Duars may be mentioned as dealing with areas lying west of Bhutan. Eastward of Bhutan we have Godwin-Austen's[2] account of his expedition into the Daphla hills, LaTouche's[3] of that into the Akas and more recently Maclaren's[4] work, north-east of Dibrugarh. The observations recorded by these various geologists had led us to form some idea of the geological formations, which one could expect to find all along the border of the Sub-Himálayas. My own results have entirely confirmed these suspicions, and one has therefore so much the less hesitation in concluding that, right away from Nepal to the Subansiri river, or even further east still, there are more or less continuous outcrops of the Upper Siwáliks, Gondwánas, Purána metamorphic rocks, and older gneiss, taking them in the order in which one meets them going inward from the plains into the hills.

Journey to the hills.

Starting from Gauhati on the Brahmaputra river and marching due north, the hills of gneiss were soon left and a flat grass-covered plain stretched away to the foot of the hills, broken only here and there by thin jungle consisting chiefly of

[1] Mem. Geol. Surv. Ind., XI, pp. 1—96, 1874.
[2] Jour. As. Soc. Beng., Vol. XLIV, pt. ii, p. 35, 1875.
[3] Rec. Geol. Surv. Ind. XVIII, p. 122, 1885.
[4] Rec. Geol. Surv. Ind., XXXI, p. 179, 1904.

the "Khair," *Acacia catechu*, and the cotton tree, *Bombax malabaricum*. Further to the east in the Darran District, through which I returned, the country has a more inhabited look; tea gardens and villages are more frequent. The true Sub-Himálayan rainy forest with its rainfall of upwards of 300 inches and its wealth of vegetation of every kind does not start until the hills are reached. This dense growth with the thick soil cap which it engenders effectually conceals the rocks except along the streams and often even there, or where a landslip carrying with it trees and soil has laid bare a hill side.

Recent or sub-recent.

Around the debouchement of each river into the plains is a collection of unstratified drift containing numerous pebbles and boulders. This is to be seen unconformably overlying the blue Siwálik clays and sandstones and forming the surfaces of many of the hills which border the plain, and rise to some 200 feet above it. The core of these low hills consists of Siwálik rocks as is proved by sections found in the small streams, which wind among them. This drift does not appear to be as largely represented here as La Touche found to be the case in the Aka hills. Nor can I find any reason for considering it as older than recent or sub-recent. I have not indicated it on the accompanying map, in which I have left all the plain portion uncoloured, while the outer hills are coloured as Siwálik, the superficial accumulations of drift being disregarded.

Siwaliks.

I crossed the entire band of Siwáliks in three different places,—north of Shobonkhata, between Daranga and Diwangiri and in the Kala Pani. In all these cases approximately the same sequence of beds is observed, all of them dipping with great regularity at angles of 50° to 60° towards the north-west. The outermost beds consist of blue clays with some very fine-grained, grey, argillaceous sandstones with occasional beds of indurated clay. All these beds are strongly jointed. The sandstones still further in become coarser and are of the micaceous pepper and salt type, and further in again occur the pebbly sandstones, containing only a few small pebbles at first, but gradually becoming regular conglomerates. The pebbles are generally of the size of a large orange, though some of them are as big as a man's head. They are almost invariably composed of quartzite. I saw also fragments of carbonaceous shale, but found no pebbles of gneiss. On leaving Shobonkhata, a march of 1½ miles up the Pagla Dia river brings us to the junction of two streams at the small village of Derutsokek, one going eastward towards Diwangiri and the other to the north-west. It was along the latter of these that our main route lay. The Siwáliks continued for about 2 miles after leaving the river junction, corresponding to a thickness of about 10,000 feet. The sandstones are evidently extremely ferruginous, for small streams issuing from the joints in the rock and precipitating a thick red deposit of ferric hydrate were very frequent.

I saw in more than one place nests and radiating strings of lignite showing in some places the cellular structure of the wood from which it was derived and in others having a strong conchoidal fracture with glistening surfaces.

Gondwánas.

As mentioned by Mallet and previous observers, the Gondwána beds of this area occupy thin bands on the inner side of the Siwáliks. Mallet has mapped them in the Baxa Duars in small lenticular outcrops. It seems not impossible, however, that the band may be more continuous than this, there being two circumstances which may tend to prevent their discovery; these are:—

1. The completeness with which the coal seams and softer beds of the series are concealed by the dense soil cap and jungle. This is so even in the river beds. Here the presence of softer beds is occasionally indicated by the sudden widening of the valley.

2. The resemblance which some of the Gondwána quartzites and graphitic schists bear to similar beds belonging to the Purána group of strata.

In the Kala Pani about two miles above its debouchement into the plains a section of the Gondwánas is magnificently exposed by a landslip. This section is shown in the sketch in plate 6, fig. 2 and a partial description of it appears in my paper on the coal occurrences in the foot-hills of Bhutan.

The total thickness of Gondwánas exposed is about 500 feet. The lowest beds seen are a very soft fine sandstone, which, weathering into innumerable small crags or pinnacles, presents a most remarkable appearance, which reminded me of nothing so much as that assumed by formations rich in salt or some other soluble substance. Interbedded with this sandstone are various coal seams; these appear to have been once continuous, but the crushing to which they have been subjected has thinned them out in places so rapidly that there are now only lenticles of coal to be seen. As has been fully explained in the paper quoted the flaky or dusty condition of the coal is due to the intensity of its crushing. The upper 300 feet of strata are of hard quartzitic sandstones, with thin sheets of carbonaceous matter alternating with them and occasional beds of shale. I found no fossil plants in these beds, but their lithological resemblance to the Gondwánas of the Sub-Himálayan region is sufficient proof of their identity. The section occurs on the line of an overthrust fault, and the boundary between the two formations is likely to prove of a similar nature elsewhere in this area.

The way in which reverse faulting has taken place in the outer Himálayas has been fully described and explained by others, and it is therefore needless to enter into the question, beyond pointing out the clearness with which the present section illustrates the phenomenon. The Gondwána beds are seen to turn over against the Siwálik conglomerates, which have acted as a sliding plane for the older coal beds. The fault evidently marks the approximate limit of deposition of the Siwáliks, as the latter do not seem to be met with overlying the Gondwánas, further on in the hills. There can be no doubt that the same band of Gondwána rocks extends a considerable distance on either side of the Kala Pani. In the Bor Naddi, 12 miles farther to the west, and in the Nunai Naddi, 4 miles to the east, precisely similar coal is found. Round Diwangiri I found several fragments of quartzitic sandstone and ferruginous shales which I assigned to the same formation. I thought that a small outcrop of carbonaceous shale south of Diwangiri might possibly be also Gondwána, but have inclined to the idea that it is similar to a graphitic schist, which I found in the Pagla Dia on about the same strike, and which, from its association with grey, schistose slates of a Daling type, I have little doubt must be Purána. Reports of coal, similar to that of the Kala Pani, much further west in the Manás river have led to my putting in a patch of Gondwána colour on the assumption that it is probably coal of that age.

Puranas.

There can be little doubt that the rocks called by Mallet Dalings and Baxas belong to this group. Misled by the dips of the strata and failing to recognize the possibility of reverse faulting, Mallet considered the Dalings younger than the Gondwánas and was unable to make up his mind about the Baxas. Since then the intenser degree of metamorphism to which these rocks have been subjected has been considered to be proof that their age is greater than that of the Gondwánas of this area which still in a large measure retain their original character and their fossils.[1] Subsequent work in other areas has familiarized us with the overfolding and reverse faulting so universally prevalent in the Himálayas.

I encountered no other rocks than those included in this group during the whole of my journey between the Siwálik boundary in the Pagla Dia river and the Kuru Chhu river—the farthest point I reached.

Massive quartzite formation.

The most prominent rock formation is a white quartzite which cannot be less than 10,000 feet in thickness, and is for the most part remarkably constant throughout its vertical extent.

In the course of my journey I came across this great quartzite formation in no less than three different places, in all of which its thickness, general character and constancy was the same.

First, ascending the western branch of the Pagla Dia river, after passing over various slates and schists we reach massive quartzite about three miles after leaving the Siwálik boundary; these quartzites form precipitous cliffs 5,000 feet high on the western side of the river, dipping at first 15°N, but afterwards increasing to 30°N. Apparently overlying them are red schistose slates containing layers of quartz. These weather into a bright red clay, which forms the surface of the path for a great distance leading up to the Monastery on the summit of Tungka La.

From this point a great change comes over the character of the vegetation corresponding to a zone of smaller rainfall. The country is just as much cut up by valleys and spurs running in every direction and there is hardly a level piece of ground to be found in the whole country, but we have left behind the overpowering luxuriance of the rainy forest of the foot-hills; rocky hill sides bare of almost every thing except *Pinus longifolia* are no uncommon sight even at elevations of 2,000 to 3,000 feet only. On the slopes of Tungka La are forests of oak, absolutely devoid of undergrowth, with a soil covered only by the decaying oak leaves of the past year. Corresponding to the increased elevation, flaming trees of *Rhododendron arborcum* strike the eye everywhere.

There are few villages, and they are but small ones and the traveller

[1] This conclusion has been expressed by Mr. R. D. Oldham in the Manual of Indian Geology, 2nd ed., p. 76.

is impressed by the comparatively unpopulated character of the country.

Going down the Kongra Chhu the quartzite is again seen, continuing without interruption to some distance on the other side of the Manás river. Its direction of dip has changed and is now southerly at an angle of about 50°.

The third place where the quartzite is seen is on the descent of the spur to the Kuru Chhu river. I ascended the river for some 4 miles after first sighting it and saw nothing else but quartzite dipping from 45° to 60°N.

As Mallet's Daling series contains only an insignificant thickness of quartzite while he mentions it as of frequent occurrence in the Baxas there seems no doubt that we must refer this quartzite to the latter series. It is true that on page 35 of his memoir Mallet, in describing the only section given, mentions 1,000 feet of quartzite, but the section is probably a short one and much greater thickness of quartzite may occur.

Dolomitic formation.

The other characteristic bed, which makes it certain that we are here dealing with Mallet's Baxa series, is a dolomitic limestone containing nests of calcite just as Mallet describes in the Baxa Duars. The only place where I saw any considerable thickness of massive dolomite exposed was on the nothern side of Kenga La. Here the dip is uniformly to the south about 60°. The dolomite is first seen on the side of a small hill in the village of Kenga, then, after crossing a valley where softer slates are exposed, we come to a thickness of about 1,500 feet of massive dolomite. The dolomitic soil nourishes amid the crags a great abundance of the beautiful *Saxifraga ligulata* and the rather rare ground orchid *Cypripedium farnianum.*

The dolomite in places seems to have undergone extensive silicification, as one finds thick beds of a powdery white jasper in contact with it. The latter is often left in the form of thin bands or lenticles in the jasper, while in other places it is the dolomite which predominates, and the jasper occurs in thin layers in the midst of it, showing that there has been secondary replacement in varying amounts.

The dolomite passes into thin bedded calcareous slates, and below these are flaggy quartzites and quartz schists, which are wholly different in appearance from the massive quartzites mentioned above. Alternating with these are thin beds of dolomitic limestone which pass into more slaty beds.

In spite of the fact that all these beds are dipping under towards the quartzites of the Manás river, I think it is almost certain that they are higher in the series. For if they were below the quartzites they would most certainly have been found between Tungka La and the plains, where on our ascent of the Pagla Dia frequent exposures of the rocks were visible proving them to be slates and schists.

Mr. Mallet's opinion also was that the dolomites were the highest member of the Baxa series, which is borne out by the section he gives in the Baxa Duars.

I consider therefore that the series of beds on Kenga La form a sharply folded syncline over which the older beds have been thrust in opposite directions (see Pl. 6, fig. 1). As I have mentioned before there is an indication of a repetition of the same band of massive dolomite near the village of Kenga. Moreover the greasy schists which one sees below Kenga are for a short distance dipping in a distinctly northerly direction, while the great mass of beds has a southerly dip. The northerly dip occurs at the faulted junction.

It was to be expected that south of the Manás river the dolomitic part of the series would be encountered overlying the quartzites and forming another syncline. The failure to recognize the northerly dipping part of these beds on the slopes of Tungka La is doubtless due to its having been faulted up and denuded. There seems no doubt however that the southerly dipping part of the dolomitic syncline is partially represented. South of the Diri Chhu above the quartzites during the ascent of the steep spur to Karu Gömpa I noticed several beds of thin bedded slates with dolomite layers, which are evidently the same as the Kenga La beds. Large accumulations of calcareous tufa in the valley of the Kangra Chhu are doubtless due to the presence of the dolomitic limestone in the neighbourhood.

There also occur in the Kangra Chhu Valley thick beds of gypsum. I did not myself see it *in situ*, not having found time to visit the locality, so can say nothing as to its mode of occurrence. But in consequence of the discovery of a fragment of rock gypsum in the bed of the Diri Chhu I sent a man to the spot, who brought back numerous specimens and information as to the extent of the gypsum. It seems probable that as at Naini Tál the dolomite has been converted into gypsum by the action of sulphuretted hydrogen derived from pyritous shales, but whether the

Gypsum.

conversion of the dolomite has taken place *in situ* or only in talus heaps as described by Mr. C. S. Middlemiss in the case of the gypsum of the Nehal Nadi, Kumaun, I am uncertain.

Daling series.

Between Kenga La and the Kuru Chhu, as before mentioned, the beds underlying the dolomites are faulted against a series of grey schists sometimes carbonaceous which pass up into the massive quartzites of the Kuru Chhu. The fault is however a subsidiary one to that on the other side of Kenga La, by which these same grey schists, evidently the lowest beds seen, are brought up against the massive dolomites.

To consider now these lowest beds, which have hitherto been only casually mentioned. They are schists or extremely fissile slates, which unfortunately I did not often find exposed, as a thick soil cap generally concealed them from view. Where seen, however, they answer very closely to Mallet's description of the Dalings. They are grey or greenish in colour and very greasy to the feel. Occasionally they are carbonaceous and a graphitic schist met with on the Pagla Dia, not far from the Siwâlik boundary, is probably of this age. The schists commonly contain lenticular layers of quartz. They are certainly more metamorphosed than the other rocks, which I have seen in this area.

These same characters are more or less observable in each of the three places where the rocks which underlie the massive quartzites are exposed, namely, north of the Siwâlik boundary on the Pagla Dia, in juxtaposition to the dolomite north of Kenga and finally north of the Kuru Chhu river. I therefore think it not unlikely that these correspond to Mallet's Dalings.

In the Aka Hills LaTouche came across neither dolomite nor quartzite, but he seems to have had no hesitation in assigning the schists he met with to the Daling series. In the Baxa Duars the Baxa series is developed at the expense of the Dalings, whose presence is only surmised by Mallet. It appears therefore that originally both series were deposited along this part of the sub-Himâlayas, but ancient faulting and subsequent denudation has entirely removed one or other of them from over large areas.

One feels inclined to regard these beds as the equivalents of the dolomites and slates of Naini Tál, but the difficulty of correlating strata at a distance from one another on mere lithological resemblances is well known.

Return Journey.

On my return journey from the Diri Chhu, I ascended the spur to Karu Gömpa and kept along the ridge until the descent to the river at Raidong. The absence of continuous sections made it impossible for me to form much idea of the geology of the country, beyond the bare knowledge that I was travelling on Purána rocks. In the river bed massive quartzites were exposed succeeded by green and grey schists much as was the case in the Pagla Dia.

My journey eastward along the base of the hills and the description of the country round the Kala Pani will be found in the following paper on the coal occurrences of Bhutan.

REPORT ON THE COAL OCCURRENCES IN THE FOOT-HILLS OF BHUTAN. BY GUY E. PILGRIM, B.Sc., *Deputy Superintendent, Geological Survey of India.*

Situation of the Coal locality of the Kala Pani.

THE coal seams, which it was my primary object to investigate, are situated in a small tributary nullah, running E.N.E. to W.S.W., leading into the Kala Pani at a point about two miles from its debouchement into the plains. The Kala Pani, marked in many places on the maps as the Demakoosum naddi, leaves the hills at Lat. 26° 55′, Long. 91° 55′, just a little west of the 102nd boundary pillar on the Bhutan Frontier and joins the Nunai naddi at Bhutia Chang tea-garden some 10 miles away. The Nunai after uniting with the Bor runs into the Brahmaputra at Gauhati.

Description of the country around the Kala Pani.

After having accompanied Mr. J. Claude White some distance into the interior of Bhutan, and having returned to Daranga near the 94th boundary pillar, I then went with him along the border of the hills to the east past the Bor Naddi to the Kala Pani and on the 9th of February last pitched my camp about 2½ miles from the coal locality. The river bed is here about 1¼ mile across, with low banks varying in height from 4 up to 10 feet.

The alluvial fan occupies a very much broader stretch of flat ground three or four miles across. The hills and the portions of the plains bordering them are densely covered with an impenetrable mass of forest and tangled undergrowth, so that prospecting will be a difficult and expensive undertaking.

The coal-locality is therefore within the Bhutan Frontier and it, along with all the foot-hills of Bhutan, has been leased by the Tongsa to Ugyen Kazi. The latter gave me every facility for digging out as large quantities of coal as I desired.

Exposure of the Coal.

The coal has been well exposed, for a distance of about a furlong, by a big landslip, which has been in progress during the last six years, and a section of some

500 feet in thickness is displayed on the hillside. The material carried down by the landslip has spread out and accumulated to such an extent that the Kala Pani has been partially blocked up and a lake has been created. This prevented my going further up the naddi.

Age of the Coal.

The coal strata are of Gondwana age, that is to say, the same as the Darjeeling coal and also that found by LaTouche in the Aka hills and by Godwin-Austen in the Daphla hills. Like all these, therefore, its formation belongs to the same period as that of the Bengal Coal Fields, although the conditions which have tilted the strata and formed them into mountains have also considerably altered the character of the coal.

Geological occurrence of the Coal Seams.

The coal of the Kala Pani lies practically on the line of a big reversed fault, along which the Gondwana beds have been thrust over the much newer Siwalik sandstones and conglomerates of pliocene age. The sketch section (Pl. 6, fig. 2) on the scale of 12 inches to 1 mile, will explain the relation of the Gondwanas and their contained coal seams to the Siwáliks. The coal seams are seen to be dipping in opposite directions on the two sides of the nullah, but the dip on the southern side is due to the beds turning over against the fault and they very soon come to an end. On the northern side the beds dip in a N. or N.N.W. direction at angles of from 40° to 75°. The coal seams are in many places even at a greater inclination than this. The upper 300 feet of strata consist for the most part of hard quartzitic sandstones with often thin sheets of carbonaceous matter alternating with them. Besides these are beds of shale, often carbonaceous and in one case a thin seam only a few inches thick, of coal, somewhat like that seen lower down.

Below this occurs the coal low down on the sides of the nullah. It is interbedded with a soft crumbly sandstone, which falls away at the slightest touch. The coal itself has also been reduced by crushing to such a flaky condition that it is exceedingly friable, and it is impossible to dig it out except in the form of dust. Nor is this soft friable condition of both the coal and the sandstone in contact with it, to be explained on the assumption that it is near the outcrop. For in the first place owing to the landslip, the coal which I had an opportunity to examine was not an ordinary weathered outcrop but a comparatively fresh surface, which previous to the landslip had been protected by many feet of overlying soil. In the second place it is clear that the powdery condition is due to the coal having been subjected to intense pressure. Hence this condition will prevail throughout the seam, and no matter how far one penetrates beneath the surface will there be any hope of improvement. As a consequence of the insecure nature both of the coal and of the sandstones which would form the roof and floor of the seams, it would be necessary to incur considerable expense in the working by having to use heavy timbering throughout.

Furthermore in the Kala Pani this does not seem to have been the only result of the crushing to which the coal has been subjected, but the effect of the shearing of the strata along the thrust plane has been to squeeze out the seams into small lenticles. These are often vertically shifted, so that the strike of the seams is no more persistent than their thickness. To such an extent is this the case that it became a matter of great difficulty to identify and assign to their proper position the various lenticular patches which represent the original coal seam. This will increase the difficulty of working the coal and also render prospecting operations more laborious and less conclusive. The greatest thickness of coal that I saw in any one seam was 3 feet, but within 20 feet this had thinned away to nothing, and this is a fair sample of them all. One seems to trace the remains of six seams having a thickness of two feet. I do not however mean by this that the thickness of two feet is persistent, but rather represents the average maximum of each lenticle.

The powdery nature of this coal caused by its intense crushing is a feature which it shares in common with that of the Darjeeling area explored in detail by P. N. Bose in 1890 and with that of the Aka and Daphla hills. We may therefore regard it as practically certain that it will prove to be a constant character of all the Gondwana coal of the Sub-Himálayas. I am not aware that the lenticular nature of the seams is a character which has been noticed in the Darjeeling area, and it may here be due to the coal outcrops being almost coincident with a line of fault.

Quality and Analysis of the Coal.

To test the quality of the coal, tests were taken in the furnace of the tea-factory of Oranga Juli, thanks to the kindness of Mr. Hill, the manager, and an analysis has been made in the Laboratory of the Geological Survey. Some one hundred maunds of coal were dug out by the Bhutanese from half a dozen promising places, and a sample maund of this, taken down to Calcutta, gave the following result on analysis :—

Moisture	1·82
Volatile matter	19·06
Fixed Carbon	54·87
Ash	24·25
	100·00

The ash is of a very pale grey colour, which indicates the absence of sulphur, and the coal cakes strongly.

In the furnace the combustion at first, when used beneath a cold boiler, was slow. When 50 lbs. of steam had been raised by Assam coal and then the Kala Pani coal placed on the glowing bed, steam rose rapidly to 100 lbs. and blew off. The coal caked exceedingly well and hardly any fell through the furnace bars. It will be seen that the ash is very high and therefore the coal cannot be considered of good quality. The small amount of volatile matter is a character which it owes to the crushing it has undergone.

Accessibility.

The Kala Pani coal is fairly accessible. A railway extension from Dhubri to Dibrugarh is at present under construction, and in the event of the coal being worked on a large scale, the E. B. S. Railway would be prepared to carry a branch track of some 10 miles to within 1½ miles of the coal, which could be run down by tramway along the hillside above the naddi.

Labour.

Labour, however, does not appear to be plentiful. None of it is indigenous. The indentured coolies in the tea gardens earn from 3 to 3½ annas per day.

It seems, however, improbable considering the nature of the beds, their high inclination, and the quality and smallness of the seams, that the cost of mining could be other than high, and this would prevent it from being able to compete successfully at Dhubri with the Upper Assam coal.

To consider now the question as to whether prospecting operations in the neighbourhood would be warranted.

Other Coal outcrops the neighbourhood.

Owing to the denseness of the jungle and the difficulty of the ground I was not able to observe any coal outcrops outside the limit of about 400 yards. I heard, however, after I had left the immediate locality, of the existence of coal some 12 miles farther to the west along the strike, in the Bor Naddi, only here the coal is 8 miles from the plains.

I received a large sample of this, which on analysis gave the following result:—

Analysis of the Bor Naddi Coal.

Moisture	1·28
Volatile matter	20·78
Fixed Carbon	38·62
Ash	39·32

The coal cakes strongly and the ash is grey coloured.

It appears therefore that the coal is inferior in quality to that of the Kala Pani and is also much more inaccessible. I also know of the existence of a very similar coal seam in the Nunai Naddi to the east, some 5 miles from the plain. An analysis of this was made in Calcutta some while ago, I am unaware by whom, with an even worse result than that of the Bor Naddi coal.

It seems probable therefore that coal exists more or less all along this strike, that is to say, over a distance of some 16 miles.

I did not find anything beyond thin beds of carbonaceous shale, in crossing the Gondwana band at two different places near Diwangiri; still it is possible that I may have missed the coal in the jungle.

Coal has been reported from the Manás river 40 miles further west.

We have good grounds for supposing that the junction of the Gondwanas and the Siwaliks is always marked by a reverse fault and accompanying this the conditions for producing considerable crushing of soft beds will invariably be present. This has been proved in several areas as mentioned above.

It is true that the coal seams in the Darjeeling area vary very much in quality and quantity, and it is not unlikely that they do so in Bhutan.

Prospecting operations in the future.

I should be unwilling therefore to assert that careful prospecting within the 16 miles of country referred to above would not disclose more promising outcrops. When, however, one remembers that seams of five times the thickness in the Darjeeling area have not proved workable, one would hesitate to expect much in an area, where the outcrops and conditions so far observed are still more unfavourable. I should therefore feel disinclined to recommend any capital being sunk in prospecting operations, which would certainly be expensive and would probably be useless.

Mining of coal on the small scale by the Bhutanese.

As to whether the Bhutanese themselves will find it profitable to work the Kala Pani coal and place it into competition with the Assam coal in the various tea-gardens between the hills and the river is another question.

Assuming that there is a thickness of 12 feet of coal over an outcrop of 900 feet and that for each seam an average depth of 50 feet of coal—down to the level of the bed of the main naddi—were worked, one can estimate the quantity of coal actually in sight as 20,000 tons.

At the present moment Assam coal costs the various tea-gardens from R12 to R20 a ton according to their respective distances from the river.

Therefore if the Bhutanese can find it possible to remove that portion of the hillside which contains the coal at a cost which will allow them to supply it below this figure, there should be no difficulty in winning the whole of this quantity with such means as are at their disposal.

If should however be remarked that the completion of the new railway in two years' time will probably cheapen the cost of Upper Assam coal for the tea-gardens, without providing a new market for the Bhutan article, since the high ash-contents of the Kala Pani coal would minimize the demand for it on the railway in question.

THE DANDLI COAL-FIELD: NOTES ON A VISIT TO THE COAL OUTCROPS IN THE KOTLI TEHSIL OF THE JAMMU STATE. BY C. M. P. WRIGHT, M.I.M.M. (With Plate 7.)

THIS field might be termed the Dandli coal-field after the village of that name where coal was first seen (H. B. Medlicott, Rec., G. S. I., IX, p. 53). Attached is a sketch map of the area (Pl. 7).

The country traversed is mountainous throughout, rising at Ranjoti Station to 6,250 feet. Deep gorges have been cut through the limestone; these form a marked feature in the scenery and are a great hindrance to travelling.

The geology of the area is similar in all respects to that of the Jammu coal-field as described by Mr. R. R. Simpson in *Memoirs, Geol. Surv. Ind.*, Vol. XXXII, pt. 4, the Dandli coal-field being the north-westerly extension of the same rocks. There is a central core or mass of "great limestone" forming either a hog-backed ridge as at Kamrot and Leri or a narrow-topped ridge as at Karjai and Ranjoti, always with a faulted, precipitous southern scarp. It is within this area a fairly regular twin anticlinal, with its component beds dipping gently on the southern edge and rather steeply to the north-east in a bow along the northern flank. Within my observation (which was specially directed to the coal measures and therefore not too observant of the limestone) it lies in thick beds. At Sangarmarg about 2,500 feet below the breccia, occur two thick beds of calcareous grit; these were seen also in the Dandli gorge. No fossils were seen. The topmost bed is a breccia, composed of limestone carrying angular fragments of quartzite of all sizes up to 10 inches in length, its thickness varies but it is always present in this area. I would feel inclined to follow Medlicott in attributing the origin of this bed to pressure alone;[1] thin interbedded sandstones, siliceous shales and limestones having been broken up and jumbled together by the forces

[1] l. c., p. 54.

which folded the strata in an anticlinal over 100 miles in length. That the forces exerted were sufficient to alter the sandstones to quartzites can be seen at Sangarmarg. The angular fragments composing the breccia are clearly defined with an occasional appearance of rounding, but without the scratching or chipping such as would be expected if the edges had been rolled.

Along both flanks of the limestone conformably occur the Subathu beds. I attach a section taken at Krela.

Section near Krela Village.

		Ft.	Ins.
Subathu.	Olive shales with bands of nummulitic limestone and occasional marly layers . .	436	0
	Two strings of coal 2½″ and 1″ in thickness .	0	3½
	Olive shales	94	0
	Grey shales with bands of marl . . .	8	9
	Coaly shales with 12 inches of coal . .	2	3
	Clay ironstone	8	6
Pre-Tertiary.	Breccia.		
	Great Limestone.		

This section would appear to support Mr. Simpson's view that the group increases in thickness towards the west. At Krela the nummulitic beds were noticeably fossiliferous, at Dhanna in the Poonch river a nummulitic band about 125 feet above the breccia being crowded with shells.

In the lower portion of the Subathu rocks occur two seams of coal and some irregular strings of an inch or two in thickness. Lydekker on p. 91 of his Memoir, The Geology of Kashmir and Chamba (*Mem., G. S. I.*, XXII) writes "there occurs a layer of carbonaceous matter, with occasional thin strings and small pockets of pure coal which, together with the similar deposits already noticed as occurring in the overlying Murree beds, have been the fruitful source of much mis-spent energy and baseless expectations." The Subathu beds are all soft and easily removed; the streams cut through them until the breccia is reached, then cut them back, denuding the Great Limestone of its cover. Coal outcrops are frequent and when not obscured by debris are seen to be continuous.

The outcrops visited and measured within the various village areas are as follows :—

(1) Name of village.	(2) Number of seams and quality.	(3) Thickness of upper seam at various points.	(4) Thickness of lower seam at various points.
Nar . . .	2 { dirty coal fair coal . }	20" + 7" + 4"	4" + 4" + 4"
Krela . .	2 fair " . .	3" + 2" + 4"	14" + 12" + 11"
Saleyta . .	4 seams . .	10" + 6" + 4" + 4"	
Gihan (galli) .	1 fair . . .	4" + 4"	Carb. shale
Bramoch . .	1 fair . . .	......	30"
Aghar . .	2 poor . . .	4" + 3"	4" + 5"
Mari . .	A jumble of coaly stuff and shales		
Kamrot stream .	1 seam fair . .	......	34"
Upper Kamrot or Panag.	2 seams fair .	2"	13"
Panag (lower) .	1 seam fair . .	......	4" + 3" + 7"
Dandli . .	2 seams fair . .	2" + 3" + 3"	3" + 4" + 7"
Fawali (Mendli)	2 seams fair . .	7" + 10"	4" + 3"
Do. Savar kas	4 seams poor inter-bedded with clay ironstone	2" + 4" + 6" + 4"	
Leri . .	2 poor . . .	3"	4"
Dhanna . .	1 dirty . . .	10"	Carb. shale
In all the above villages the outcrops are upon or near the limestone breccia :—			
Chinjoora .	Coaly shale with thin seams of coal.		
Dhanwa . .	1 seam . . .	4"	
Naroli . .	1 seam fair . .	16" + 4" + 20" + 36" + 7" + 12" + 13" + 21" + 8"	
Salun . .	1 seam fair . .	16" + 6" + 8"	
Mera . .	1 seam fair . .	18"	
Nikyal . .	2 seams . . .	dirty 36"	fair 4"
Tangal (S.E. of Mera) coal and shale crushed together.			
Kandar: frequent exposures for ¾ mile along bank of stream; dirty to fair, rather pyritous coal.		16" + 24" + 27"	

In these villages to the north of the limestone core, the better coal lies in an horizon about 70 ft. above the breccia as at Mehowgala: its quality may be compared to that of the Sangarmarg area.

From these notes it will be seen that the coal of the Dandli field is not of good quality nor of any thickness: it is irregular throughout: the seams are usually highly inclined and in places contorted: coupling with these objectionable features the long distance from the North-Western Railway and entire absence of local demand, the field either in part or as a whole offers no inducement to exploitation.

MISCELLANEOUS NOTES.

On samples of mud from Narrakal, Alleppy and Calicut at the smooth-water anchorages on the Travancore Coast.

THE muds, which were received in three 4-gallon tins, had a peculiar greenish-black appearance and unctuous feeling. When the samples were examined in the tins, the mud had more or less subsided leaving an upper layer of ordinary sea-water. For the purposes of analysis and to ascertain the chemical nature of the mud itself, a sufficiency of each variety was washed with distilled water, to free it from the soluble salts present in the sea-water. The samples were finally dried at 100° C., and after drying assumed the appearance of ordinary river-mud, with absolutely no tendency to oiliness or stickiness.

The dried muds had a grey-brown appearance and had caked into hard lumps, which required powdering in a mortar and re-drying in order to remove all hygroscopic moisture.

The analyses were conducted on these dried and powdered samples, and the results obtained are set forth below:—

	Narrakal Mud.	Alleppy Mud.	Calicut Mud.
Volatile and organic matter (includes combined water, organic matter and carbon dioxide)	17·03	11·81	14·36
Silica	41·44	46·43	44·29
Ferric Oxide	4·92	3·61	4·80
Ferrous "	4·35	3·13	3·45
Aluminium Oxide	20·70	18·08	18·66
Lime	4·11	7·54	6·87
Magnesia	5·01	6·04	4·99
Sulphuric Anhydride	1·71	2·64	2·44
Phosphoric "	0·46	0·32	0·36
	99·73	99·60	100·22
Bituminous and other organic matter soluble in ether	0·84%	1·003%	2·25%
Oil obtained on destructive distillation	0·83%	0·45%	0·5%

In Dr. King's "Considerations on the smooth water anchorages, or mud banks of Narrakal and Alleppy on the Tranvancore Coast" (*Rec., Geol. Surv. Ind.*, Feby. 1884) he states that samples of these muds were assayed by his colleague, Mr. Mallet, who in the course of his report writes :—

"All gave off, when subjected to distillation, some brownish-yellow oily matter, lighter than water and looking not unlike petroleum—1019 and 1021 (nos. of samples) were digested with ether, which extracted a small quantity of a brownish-yellow greasy matter from them." Other observers, P. Lake ("Notes on the mud bank of the Travancore Coast," *Rec.*, *Geol. Surv. Ind.*, 1890) and Messrs. Crawford and Rhode, late Commercial Agents at Alleppy, were evidently of the opinion that the soft oleaginous character of the muds was due to the presence of oil and the existence of this oil has been accepted by some as a feasible explanation of the action of the muds in preventing the breaking of the waves at the smooth-water anchorages. Now, if oil were present, even in a fairly small quantity in these muds, it is hardly likely that it would disappear when the muds were washed with distilled water, or dried at a temperature of 100°C, unless of course the oil were very volatile, an improbable contingency.

As I have indicated above, the muds had the soft unctuous feeling only when wet. This characteristic disappeared entirely after drying, and they assumed the appearance of ordinary clays of a very fine texture, with no trace of oiliness. Again, if oil were pre-existent in the mud, it would be readily extracted by ether. As shown in my report, experiments were conducted with the washed muds in order to ascertain the quantity and nature of the matter soluble in ether.

The ethereal extract was in each case of a yellow colour, and left a brownish-yellow residue, which however was too small in quantity, even when a large amount of mud was operated upon, to enable its nature to be determined with certainty. The residue was of a decidedly greasy nature, and in my opinion was more bituminous than oily, and was probably the result of the partial decomposition of organic remains, animal and vegetable. Referring again to the report quoted above, the fact that an oil was obtained on destructive distillation of the muds, cannot be taken as evidence that such oil is pre-existent in these substances. The analyses shew that organic matter is present and as most, if not all, substances in the animal and vegetable kingdom, or mineral substances containing organic matter, will yield oils as a portion of the products of destructive distillation, the fact that oil was obtained in the cases under consideration is only what might be naturally expected.

As the oil was obtained in very small quantity it could not be examined very fully, but I have little hesitation in stating that it was of a nitrogenous non-saponifiable character, and possibly derived from animal remains in the muds. It had a strong pungent odour, characteristic of pyridine, quinoline, etc., substances obtained by distillation of bones and similar nitrogenous animal remains, but not occurring in petroleum. A microscopic examination of the muds revealed the presence of minute quartz crystals indicating sand, also black particles of carbonaceous matter and minute shells.

The muds, as already mentioned, were of extremely fine texture, and subsided very slowly when stirred up in water. The action of the muds in retarding the force of the waves at the smooth-water anchorages, is probably due to their very fine state of division, which increases the density and viscosity of the water in which the mud is suspended. The fluid friction is also increased as the latter is directly proportional to the density of a liquid. The natural result is that the force or motion of the waves is more or less diminished, when they enter the area of greater density, (*i.e.*, the mud banks) owing to the partial absorption of their energy brought about by the increased fluid friction of the muddy water. Mud from the Pegu or Rangoon rivers has, when moist, a soft unctuous feeling similar to the muds of the smooth-water anchorages but contains no oil.

The chemical analysis detailed herewith indicates nothing peculiar in the composition of the muds, which are evidently composed of organic matter, clay and sand, hydrate and carbonate of iron, and sulphate, carbonate and phosphate of lime and magnesia, and are quite what might be expected with ordinary muds of littoral origin.

[R. G. NEILSON.]

Note on a boring in the Tertiary deposits of Mayurbhanj.

A boring was started in March 1905, in the Tertiary deposits at Baripada (the capital of the Mayurbhanj States), partly with a view to set at rest all doubts about the existence of coal either in association with those deposits or in possible Gondwana beds underlying them and partly to see if an Artesian supply, or an approach to it, was obtainable. The boring was put down in a well at the traveller's bungalow and was carried down to a depth of 163 ft. (including 40 feet, the depth of the well), when it had to be stopped owing to an accident. The water-bearing stratum in the well is loose sand underlying greyish-white clay. Below the sand the boring revealed the following rock sequence :—

	Feet	Ins.
Quartzose, brownish sand	20	0
Argillaceous sand	4	6
Fine brownish sand with specks of mica	5	0
Greyish or bluish white clay	3	6
Sandy clay	6	0
Fine bluish stiff clay	5	0
Gritty clay	4	0
Fine bluish stiff clay	9	0
Slightly carbonaceous gritty clay	7	0
Coarse greyish clay	2	0
Greyish gritty clay with minute spangles of mica	3	0
Fine greenish sandstone	2	0
Greyish gritty clay	2	0
Sandstone with smooth black casts of bivalves (?)	1	0
Greyish fine hard clay-stone	1	0
Sandstone with cast of a very small bivalve	1	0
Dark gritty clay with dark-coloured nodules fossil ;	2	0
Ditto (slightly carbonaceous)	2	0
Ditto coarse	2	0
Fine greyish blue clay	1	0
Limestone with fragment of an Ostrea (?)	2	0
Gritty bluish marl	2	0
Ditto (coarse)	1	0
Ditto	4	0
Ditto *with fragments of fossils*	0	6
Fine-grained brownish hard limestone	0	6
Fine bluish grey clay	4	0
Coarse ditto	2	0
Slightly calcareous gritty clay	1	0
Fine pale blue clay	1	0
Limestone with fragments of fossils	1	0
Coarse marl with fragments of fossils	1	0
Fine marl with ditto	9	6
Fine pale blue clay	5	0
Coarse gritty clay	5	6
	123	0

[The fossiliferous strata are given in italics.]

It will be seen that the base of the Tertiary formation had not been reached when the boring was closed. As the discovery of that formation in Orissa is of very great interest in Indian Geology, I venture to suggest that it be tested by a diamond boring at some suitable place by the Geological Survey of India. It will I expect prove to be widespread, and will, in all probabality, be found to underlie the laterite in the district of Midnapore.

Unfortunately, the fossils yielded by the boring are generally undeterminable. The limestone at 142 feet from the surface is crowded with *Amphistegina*. Mr. Pilgrim of the Geological Survey of India who determined the genus observes: "Although it is true that *Amphistegina* was very much more abundant in the miocene, still it is found in the seas of to-day, most commonly up to a depth of 30 fathoms. But added to the testimony of the *Ostrea*,[1] it strengthens the probability that we are dealing with a marine deposit which is at all events as old as miocene."

[P. N. BOSE.]

[1] See "Notes on the Geology and Mineral Resources of Mayurbhanj." *Rec., Geol. Surv. Ind.*, Vol. XXXI, pt. 3.

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THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1906. [September.

THE MINERAL PRODUCTION OF INDIA DURING 1905.

BY T. D. LA TOUCHE, B.A., F.G.S., *Officiating Director, Geological Survey of India.*

CONTENTS.

I.—INTRODUCTION.

THE present statement of the Mineral Production of India during 1905 follows closely the scheme laid down by Mr. Holland in the statement issued in Vol. XXXIII, Part 1, of these *Records*, in order to admit of easy comparison with the returns for previous years.

The minerals are divided into two groups—(I) those for which approximately accurate figures are available, and (II) those for which the returns are either not reliable or incomplete.

It will be observed that there is a considerable discrepancy between the amounts given for the total output of certain minerals in this statement and in the report of the Chief Inspector of Mines in India covering the same period. For instance the total output of coal is given here as 8,417,739 tons, against 7,762,779 tons in the report. The difference is merely due to the fact that the Chief Inspector of Mines does not take cognizance of mines situated in Native States, such as the Singareni colliery in Hyderabad, or the Palana colliery in Bikanir.

Total Value of Production.

A summary of the total value of the minerals produced in 1905 is given in table 1. Nearly every item shows an increase, and the total is £350,116 in excess of the values for 1904.

TABLE 1.—*Total Value of Minerals for which Returns of Production are available for the years 1904 and 1905.*

—	1904.	1905.
	£	£
Gold	*2,366,079*	2,416,966
Coal (*a*)	*1,398,826*	1,436,951
Petroleum (*a*)	*473,971*	604,203
Salt (*a*)	*437,530*	441,206
Saltpetre (*b*)	*266,349*	235,723
Manganese-ore (*b*)	*129,632*	248,309
Mica (*b*)	*97,932*	142,008
Rubies	*90,612*	88,340
Jadestone (*b*)	*50,726*	45,474
Graphite (*a*)	*16,726*	16,890
Iron-ore (*a*)	*12,617*	13,827
Tin-ore (*a*)	*8,353*	9,783
Chromite (*a*)	*4,137*	3,482
Diamonds	*2,636*	2,474
Magnesite (*a*)	*876*	1,375
Amber	*838*	945
TOTAL .	*5,357,840*	5,707,956

(*a*) Spot prices. (*b*) Export values.

The total value of the minerals of Group II, so far as they are obtainable, amounts to £160,451 as against £110,981 for 1904. The increase probably means that the returns are being more carefully compiled, and no doubt in a few years it will be possible to transfer many of the minerals of this group to Group I.

Another indication of this increase in activity as regards minerals in India is afforded by the number of licenses issued, which still shows a gratifying upward tendency. The total number granted during 1905 increased by 25 per cent. (see table 25).

Licenses granted.

Figures showing the imports and exports of mineral products during 1905 compared with the returns for previous years will be found in Vol. XXXIII, Pt. 3, of these *Records* under the heading *Miscellaneous Notes*.

II.—MINERALS OF GROUP I.

Chromite.	Graphite.	Manganese-ore.	Salt.
Coal.	Iron-ore.	Mica.	Saltpetre.
Diamonds.	Jadeite.	Petroleum.	Tin.
Gold.	Magnesite.	Rubies.	

Chromite.

THERE has been a considerable falling off in the production of chromite in Baluchistan, the only province in which it is mined, *viz.*, from 3,596 tons, valued at £4,137, in 1904, to 2,708 tons, valued at £3,482, in 1905, although two new mines were opened, producing 422 and 633 tons, respectively. The Khánozai mines, which produced 3,466 tons in 1904, yielded only 750 tons in 1905, but the production of the Hindubágh mines rose from 130 to 814 tons. The ore is raised entirely for export to Europe.

Coal.

The output of coal has again exceeded all previous records, though the increase has not been so great as in the previous year, being only 2·4 per cent. against 10·5 per cent. in 1904. As before, both Gondwana and Tertiary coalfields contributed to the increase as shown in table 2.

TABLE 2.—*Origin of Indian Coal raised in 1904 and 1905.*

—	*1904.*		**1905.**	
	Statute Tons.	*Metric Tons.*	**Statute Tons.**	*Metric Tons*
From Gondwana Coalfields . .	7,808,027	*7,933,325*	**7,993,363**	*8,121,256*
From Tertiary Coalfields . .	408,679	*415,236*	**424,376**	*431,166*
TOTAL .	8,216,706	*8,348,561*	**8,417,739**	*8,552,422*

TABLE 3.—*Provincial production of Coal for 1905 compared with that for 1904.*

PROVINCE.	*1904.*		1905.	
	Quantity.	*Value.*	Quantity.	*Value.*
	Statute Tons.	£	Statute Tons.	£
Baluchistan	49,867	*27,308*	41,725	*22,844*
Bengal	7,063,680	*1,015,147*	7,234,103	*1,041,910*
Burma	1,105	*294*	*Nil*	...
Central India	185,774	*47,060*	157,701	*40,137*
Central Provinces . . .	139,027	*43,664*	147,265	*46,241*
Eastern Bengal and Assam . .	266,765	*84,592*	277,065	*87,808*
Hyderabad	419,546	*150,345*	454,294	*159,002*
Kashmir	270	...	*Nil*	...
Punjab	45,594	*22,144*	62,622	*31,311*
Rajputana (Bikaner) . . .	45,078	*8,272*	42,964	*7,898*
TOTAL .	8,216,706	*1,398,826*	8,417,739	*1,436,951*

No coal was produced during the year either in Kashmir or Burma, but in the latter province new fields are being prospected. The colliery at Warora (Chánda) has been definitely closed, in consequence of a serious subsidence which took place in the working in March 1906. A note on this occurrence, by Mr. R. R. Simpson, Deputy

Inspector of Mines, is published in this number of the *Records*. A new field was opened at Chandameta in the Chhindwara district, Central Provinces, and produced 1,104 tons. New mines were also opened at Davispur in Baluchistan, in the Shahpur district, Punjab, and in Sambalpur, and produced small quantities of coal.

TABLE 4.—*Output of Gondwana Coalfields during 1904 and 1905.*

COALFIELDS.	1904.		1905.	
	Statute Tons.	*Per cent. of Indian Total.*	Statute Tons.	Per cent. of Indian Total.
Bengal—				
Daltonganj	50,517	·61	71,294	·85
Giridih	773,128	9·41	829,271	9·85
Jherria	2,889,504	35·17	3,070,588	36·48
Rajmahal	274	...	414	...
Raniganj	3,350,257	40·77	3,262,536	38·77
Central India—				
Umaria	185,774	2·26	157,701	1·87
Central Provinces—				
Bellarpur	90	...	148	·02 (Bellarpur and Chandameta together)
Chandameta	...	...	1,104	
Mohpani	26,618	·32	22,998	·27
Warora	112,319	1·37	123,015	1·46
Hyderabad—				
Singareni	419,546	5·11	454,294	5·38
TOTAL .	7,808,027	95·02	7,993,363	94·95

TABLE 5.—*Production of Tertiary Coal in 1904 and 1905.*

COALFIELDS.	1904.		1905.	
	Statute Tons.	*Per cent. of Indian Total.*	**Statute Tons.**	Per cent. of Indian Total.
Baluchistan—				
Khost	38,574	·47	**34,140**	·41
Sor Range, Mach, etc. . .	11,293	·14	**7,585**	·09
Burma—				
Shwebo	1,105	·02 (Shwebo and Ladda)	*Nil*	...
Kashmir—				
Ladda	270		*Nil*	...
Eastern Bengal and Assam—				
Makum	266,265	3·25 (Makum and Smaller fields)	**276,577**	3·29 (Makum and Smaller fields)
Smaller fields . . .	500		**488**	
Punjab—				
Salt Range	45,258	·55 (Salt Range and Attock district)	**61,618**	·75 (Salt Range, Attock and Shahpur)
Attock district . . .	336		**715**	
Shahpur „ . . .	...	...	**289**	
Rajputana—				
Bikanir	45,078	·55	**42,964**	·51
TOTAL .	408,679	4·98	**424,376**	5·05

Exports.

The exports of Indian coal again exceeded previous records, being 783,760 tons as against 602,810 tons in 1904 (table 6), but this amount is still only a small proportion of the quantity raised and consumed in the country. The export value remains about the same, *viz.*, from 10*s.* to 10*s.* 6*d.* per ton.

TABLE 6.—*Exports of Indian Coal during 1904 and 1905.*

Exported to	1904.	1905.
	Tons.	Tons.
Aden	*31,620*	29,312
Africa, East	*21,263*	15,034
Ceylon	*360,697*	376,853
Straits Settlements	*144,545*	229,230
Sumatra	*32,810*	33,859
Other countries	*11,875*	99,472
TOTAL .	*602,810*	783,760

Imports of coal fell off considerably, from 243,968 tons in 1904 to 188,677 tons in 1905. The cost of imported coal is more than double that of the Indian coal, being from 22 to 23 shillings per ton.

Consumption on the railways.

The amount of coal consumed on the Indian railways during 1905 was 2,668,424 tons, against 2,447,341 tons in 1904. This was 31·7 per cent. of the total production against an average of 29·7 per cent. for the previous five years.

Labour.

The average daily attendance at Indian coal mines in 1905 was 89,995, and the average output per person employed 93·5 tons, as against 88·6 tons in 1904 and 84 tons in 1903. Details of accidents in mines worked under the Mines Act of 1901 are published in the Report of the Chief Inspector of Mines.

Diamonds.

The mode of occurrence of the diamonds in the Vindhyan conglomerates of Bundelkhand, and the native methods of working the deposits, were thoroughly investigated by Mr. E. Vredenburg, who has published a full description of them in these *Records*,[1] and has proposed a more systematic plan of working than the haphazard

[1] Vol. XXXIII, Pt. 4, p. 261.

methods now employed. The output for the years 1904 and 1905 is given below:—

YEAR.	Quantity.	Value.
	Carats.	£
1904	286·48	2,636
1905	172·41	2,474

The industry gives employment to 1,890 persons.

Gold.

The Hutti Mine in the Nizam's Dominions still continues to give good results, the output since the mine began to produce gold in March 1903 having been:—

TABLE 7.—*Output of Gold from the Hutti Mine, Hyderabad.*

YEAR.	Quartz crushed.	Output of Gold.	Value.
	Tons.	Ounces.	£
1903	5,735	3,809·4	14,505
1904	17,205	10,558·6	40,624
1905	24,325	12,168	46,285
	Tailings cyanided 8,700	999	3,775
TOTAL .	55,965	27,535	105,189

Another mine in the neighbourhood, at Topaldodi, was opened, but has not yet given any returns.

In Burma prospecting is still going on in the Chindwin river, and preparations were made for starting active dredging operations on the Namma river in the Northern Shan States. The gold obtained by dredging in the Irrawaddi in the Myitkyina district increased from 216 oz. in 1904 to 620 oz. in 1905, a second dredger having been got to work in the latter year. Only one of the Dharwar mines has so far given any results. The returns for the whole of India are shown in table 8.

TABLE 8.—*Quantity and Value of Gold produced in India during 1904 and 1905.*

PROVINCE.	1904.		1905.	
	Quantity.	*Value.*	Quantity.	*Value.*
	Ounces.	£	Ounces.	£
Bombay—				
Dharwar	...	...	93	320
Burma—				
Pakkôku	...	...	1½	7
Myitkyina . . .	216	810	620	2,412
Hyderabad	10,559	40,624	13,167	50,060
Mysore	607,578	2,323,183	616,758	2,363,457
Punjab	370	1,379	176 + (*a*)	703
United Provinces	23	83	1½	7
TOTAL .	618,746	2,366,079	630,817	2,416,966

(*a*) The quantity for Umballa district is not given.

The decrease in the production of gold in the United Provinces and the Punjab, where the industry is entirely confined to native gold washing, is said to be due to the light rains of 1905. In Kashmir also the production fell off greatly, from about 26 oz. in 1904 to only 10 oz. in 1905. The gold is derived from terraces in the Indus Valley in Kargil and Skardu.

The Chota Nagpur gold washing is mainly confined to the valleys of the Karkari and Suvarnarekha rivers. The number of persons engaged in the industry fluctuates considerably, as the pepole do not depend entirely upon it for a livelihood. In Manbhum the number employed was 255 and in Singhbhum 154. The average earnings amount to only As. 1-6 a day for each person.

Graphite.

The total production of crude graphite in 1905 was 2,324 tons, valued at £16,890. Of this amount, 2,260 tons was raised in

Travancore, and the remainder in the Godávari district. The operations in this district have not advanced beyond the prospecting stage, and the mine at Perakonda has been closed.

Iron-ore.

The production of iron-ore for the whole of India rose by nearly 50 per cent. from 71,608 tons in 1904 to over 102,120 tons in 1905. The greatest increase took place in Bengal which produced 97,698 tons, or 95 per cent. of the total. The value in Bengal is returned at Rs. 1,88,076 or about Rs. 2 (2*s.* 8*d.*) a ton. Outside Bengal the local value varies enormously as given in the returns, but where it is abnormally high, as in Garhwal, where the returns give an output of one ton valued at Rs. 224, the output is correspondingly low, and the total value is not greatly affected. Taking an average of Rs. 4 a ton for all the ore raised outside Bengal, the total value for the whole of the ore raised in India is £13,827, against £12,617 in 1904.

There was a slight increase in the number of native furnaces at work in the Central Provinces.

Jadeite.

The only mines of jadeite worked are in the district of Myitkyina in Upper Burma. 2,685 cwts. were raised in 1905, of which 2,342 cwts., valued at £43,474, was exported *viâ* Rangoon, and the remainder overland to China. Compared with 1904, the amount exported was:—

ROUTE.	*1904.*		1905.	
	Weight.	*Value.*	Weight.	*Value.*
	Cwts.	£	Cwts.	£
Through Rangoon . . .	2,869	*43,946*	2,342	*43,474*
Overland	909	*6,780*	343	*2,000*
TOTAL .	3,778	*50,726*	2,685	*45,474*

Magnesite.

The amount of magnesite raised at the Chalk hills near Salem in 1905 was 2,063¼ tons, an increase of 748¼ tons over the production of 1904. The value is not given in the returns, but taking it as Rs. 10 (13*s.* 4*d.*) a ton, it would amount to £1,375.

Manganese-ore.

There was a considerable rise in the output of manganese-ore, due mainly to the temporary closure of the manganese industry in the Caucasus, owing to the troubles in Russia, and the consequent rise in the value of the mineral. The total production was 253,896 tons, valued at £82,979. The amount exported was 282,334 tons against 154,830 tons in 1904.

TABLE 9.—*Production of Manganese-ore for 1904 and 1905.*

PROVINCE.	*1904.*	1905.
	Tons.	Tons.
Central India	*11,564*	30,251
Central Provinces	*85,034*	159,950
Madras	*53,699*	63,695
TOTAL .	*150,297*	253,896

Mica.

There was a considerable rise in the exports of Indian mica during 1905, the figures being 133,159 cwts. for 1905 as against 18,250 cwts. for 1904. The total value, £142,008 against £83,183, has not risen in the same ratio, owing to the fact that in Bengal the mica now being extracted is of very inferior quality. The number of mica mines in the Madras Presidency increased from 56 in 1904 to 87 in 1905. Some mica was produced in the Ajmer district in Rajputana, and mica of fair quality is said to occur in Kishengarh

State, but does not appear to be mined as yet. The production is shown in the following table :—

TABLE 10.—*Production and Value of Mica during 1905.*

PROVINCE.	Quantity.	*Value.*	Value per cwt.
Bengal—	Cwts.	£	£
Hazaribágh	9,690		
Gaya	4,720	*24,796*	1·70
Monghyr	191		
Madras—			
Nellore	8,220	*58,699*	7·08
Nilgiris	60		
Rajputana—			
Ajmer	2,760	*1,000*	0·31
TOTAL .	25,641	*83,495*	3·27

Petroleum.

The production of petroleum remains about the same as before in Assam and the Punjab, but has largely increased in Burma.

TABLE 11.—*Production of Petroleum in 1904 and 1905.*

PROVINCE.	*1904.*	1905.
	Gallons.	Gallons.
Burma	*115,903,804*	142,063,846
Eastern Bengal and Assam	*2,585,920*	2,733,110
Punjab	*1,658*	1,488
TOTAL .	*118,491,382*	144,798,444

The increase in Burma is only 22·6 per cent. of the output for 1904, instead of 35·8 per cent. as in the previous year, but this is mainly due to the fact that the Burma Oil Company are holding a large portion of the Singu field in reserve.

TABLE 12.—*Production of the Burma Oil-fields for 1904 and 1905.*

OIL-FIELD AND DISTRICT.	1904.	1905.
	Gallons.	Gallons.
Akyab	47,082	53,455
Kyaukphyu	89,827	60,647
Yenangyaung, Magwé	73,428,960	85,648,749
Singu, Myingyán	23,677,450	37,541,177
Yenangyát, Pakókku	18,660,485	18,759,818
TOTAL .	115,903,804	142,063,846

The imports of petroleum have again shown a considerable falling off, entirely confined to Russian oil, for the amounts imported from America, the Straits Settlements, Sumatra, and Borneo have all increased.

TABLE 13.—*Imports of Foreign Kerosene during 1904 and 1905.*

—	1904.	1905.
	Gallons.	Gallons.
Russia	42,256,738	17,060,719
United States	7,628,275	18,738,137
Borneo	6,931,291	7,039,812
Straits Settlements	8,985,538	12,508,844
Sumatra	3,566,619	6,963,737
Other countries	1,222,397	16,379
TOTAL .	70,590,858	62,327,628

The exports also showed a falling off of over a million gallons from 3,787,677 gallons in 1904 to 2,422,589 gallons in 1905.

Besides kerosene, 63,966 cwts. of paraffin wax were exported, of which 11,400 cwts. were produced in the Digboi refineries in Assam.

Rubies.

The output from the Ruby Mines in Upper Burma, including small quantities of sapphire and spinel, for the year ending February 28th, 1906, amounted to 266,584 carats, valued at £88,340, against 265,901 carats, valued at £90,612, in the previous year. The royalties received by the Ruby Mines Company from native miners amounted to £12,129, against £17,441 in 1904. In the Myitkyina district Rs. 240 were realised from license fees.

Salt.

There was a very slight rise in the production of salt in 1905, and a slight falling off in imports as compared with the previous year, when both were stimulated by the reduction in the salt tax. The following table shows the production in each province.

TABLE 14.—*Provincial Production of Salt during 1904 and 1905.*

—	*1904.*	1905.
	Statute Tons.	Statute Tons.
Aden	*66,007*	97,727
Bengal	*88*	3
Bombay	*430,409*	425,100
Burma	*21,387*	23,133
Gwalior State	*374*	84
Madras	*356,834*	388,670
Northern India	*282,421*	342,210
Sind	*13,540*	14,266
TOTAL, Statute Tons	1,171,060	**1,291,193**
Total, Metric Tons	*1,188,900*	*1,310,800*

The production for Northern India includes rock-salt mined in the Punjab and North-West Frontier Province. This amounted to :—

TABLE 15.—*Production of Rock-Salt during 1904 and 1905.*

—	*1904.*	1905.
	Statute Tons.	Statute Tons.
Salt Range, Puujab	*107,403*	94,048
Kohát	*16,664*	14,897
Mandi	*4,507*	3,571
TOTAL, Statute Tons	128,574	**112,416**
Total, Metric Tons	*130,635*	*114,210*

The imports of salt amounted to 433,246 tons, against 486,018 tons in 1904.

Saltpetre.

The production of saltpetre in Bengal increased very largely, from 164,702 cwts. in 1904 to 407,340 cwts. in 1905,* but there was a falling off in the exports, from 390,970 cwts. in 1904 to 313,122 cwts. in 1905.

The figures for the Punjab and United Provinces have not yet been furnished.

Tin-ore.

The output of tin in Mergui and Tavoy amounted to 1,495 cwts., valued at £9,783, against 1,388 cwts., valued at £8,242, in 1904. No returns of the tin raised in the Bawlake State, Karenni, have been sent in.

* From information received after this statement was sent to press, it appears that the figures for 1905, as given in the returns, refer to *crude saltpetre* produced in the whole of Bengal, whereas the figures for 1904 refer to *refined saltpetre* produced in Behar district *only*.

III.—MINERALS OF GROUP II.

THE following notes deal with the minerals of Group II, the returns for which are incomplete.

Alum.

The principal source of alum is in the Mianwáli district of the Punjab, where 7,126 cwts. were produced, valued at £2,038. In 1904 the production was 2,580 cwts., valued at £700. The imports of alum in 1905 were 73,456 cwts., valued at £22,360.

Amber.

The amber raised in the Myitkyina district of Burma in 1905 amounted to 126 cwts., valued at £945. The output has risen from 86 cwts. in 1904, on account, it is said, of the peaceful state of the country, but the value has fallen from £9 15*s*. to £7 10*s*. per cwt. owing to the larger output and the inferior quality of the amber now produced.

Arsenic.

No white arsenic is produced in the country, but a small quantity of realgar is brought in from Kumaon and sold in the bazaars of Northern India. The imports of arsenic in 1905 were 2,629 cwts., valued at £3,374.

Bauxite.

This mineral is beginning to attract attention in the Central Provinces, and several prospecting licenses have been granted in connection with it, but none has yet been placed on the market. Nor is it likely that this can be done with profit until plant is erected on the spot for the preparation of pure calcined alumina from the crude mineral.

Borax.

The trade in borax through Kashmir is being put on a more satisfactory footing, and two contracts for its supply, to run for three years each, have been sanctioned by the Durbar. No returns of the production for 1905 have been received. The exports were 4,198 cwts., valued at £5,246.

Building stone.

Excepting Burma, only partial returns of the production of building stone are available, and it is not always clear whether the stone is used for building purposes or for road metal. The returns sent in are—

	Material.	Quantity.	Value.
		Statute Tons.	£
Burma . . .	Granite . . .	9,946	*1,348*
	Sandstone . . .	96,947	*8,862*
	TOTAL .	**106,893**	**10,210**
Coorg . . .	Granite . . .	27,788	*5,450*
Gwalior . .	Sandstone .	Slabs 75,360	*604*
		Cart-loads. 52,584	*1,915*
Hyderabad . .	'Slab' stone . .	...	*380*
	'Black' stone . .	...	*7*
Jaisalmer . .	'Badu' stone .	18	*Nominal*
Mirzapur . .	Sandstone . . .	99,850	*12,727*

Besides this, building stone to the value of £212,833, weighing 80,577 tons, was imported into the country during 1905.

Clay. The only complete returns for the extraction of clay have been received from Burma where a total quantity of 1,075,097 tons was raised, valued at £76,291. The amount depends to a great extent on the demand for bricks used in building pagodas, and this again is greater or less as the year is considered to be 'lucky' or not. During 1905 the demand seems to have been particularly brisk.

One thousand and eight hundred tons of fire-clay were raised at Warora colliery, but the value is not given. No returns are available for the clay raised in Bengal for brick-making and pottery, or for the pottery clays of Jubbulpore.

Copper-ore. Eight hundred and twenty-one and one-fourth cwts. of copper-ore, valued at £4,200, is returned as having been raised in the Mandalay district of Upper Burma, probably during prospecting operations.

Cornelian stone. Four hundred and sixty-seven tons of cornelian stone, valued at about £466, were obtained in Rajpipla State, Bombay.

Corundum. The quantity of corundum now mined in India is insignificant. In Hyderabad the value of the material raised was only £39, and in Baghelkhand in Central India 53 tons were extracted. In Madras none was produced in 1905, and only 7 tons in 1904.

The increase in the production of artificial abrasives such as carborundum, in America, seems to have practically killed the demand for the natural mineral.

Garnet. Garnets are mined in several districts in Rajputana, the output for which figures are given being about 700 cwts., averaging about £6 a cwt. in value. Besides this a large quantity is mined in Kishengarh, where the mines are open to the public for the first three and last three months of the year, and for the rest of the time are worked by the State, which employs from 200 to 600 people daily. The revenue derived from the industry is about Rs. 70,000 (£4,666) annually.

Gypsum. Four thousand and eight hundred tons of gypsum, valued at £160, were raised in Jodhpore State in Rajputana as against 3,875 tons, valued at £129, in 1904.

Limestone. The principal sources of limestone are the Khasi and Jaintia Hills in Assam, Sutna in Rewah, and Katni in the Jubbulpore district. A large quantity is lso raised in Burma. The returns available for 1905 are—

PROVINCE.	Quantity.	*Value.*
	Tons.	£
Baluchistan—		
Las Bela	566	47
Burma	44,826	6,054
Central India	...	343
Central Provinces—		
Jubbulpore	92,340	4,572
Eastern Bengal and Assam—		
Lakhimpur	1,098	300—400
Khasi and Jaintia Hills	89,884	6,880
Punjab—		
Hoshiarpur	1,000	133
Rajputana	58,737	6,250

Marble. The output of marble at the well-known quarries of Makrana in Jodhpore territory rose from 1,034 tons, valued at £1,102, in 1904, to 1,726 tons, valued at £1,840, in 1905.

A large quantity of white crystalline marble is quarried in the Sagyin hills near Mandalay, but no statistics are given. There is said to have been a greater demand for it in 1905 and the amount of fees realised for the working of the quarries was Rs. 10,220.

Slate. Slate is mainly quarried from the metamorphic rocks along the foot of the Himalayas, but some is also raised in the Kharakpur hills in Bengal and in the

Aravallis in Rajputana. The returns so far as they are available are as follows :—

—	Quantity.	*Value.*
	Tons.	£
Bengal	216	*2,484*
Punjab	62,986	*1,867*
Rajputana	25	*12*
United Provinces	11,300	*1,187*
TOTAL	**74,527**	**5,550**

The estimated value of the slate raised in 1904 was £4,628.

Steatite.

A small quantity of steatite is mined in Upper Burma, principally in the Minbu district. The amount turned out in 1905 was 244 cwts., valued at £341, against 340 cwts., valued at £540, in 1904. A small quantity was also raised in the Nizam's territory.

Tourmaline.

Tourmaline is mined to a small extent to the south of the Ruby Mines district in Upper Burma. Two hundred and thirty-two licenses were issued during the year to native prospectors, and the quantity obtained was 161 lbs., vauled at £1,500.

IV.—PROVINCIAL NOTES.

Baluchistan.

COAL and chromite are the two principal minerals raised in Baluchistan. The coal is mined at Khost, chiefly for the railways, and at a few small collieries in the Sor Range. There are several 'shows' of petroleum in the province, but none of them are now being worked.

TABLE 16.—*Prospecting and Mining Leases granted in Baluchistan during 1904 and 1905.*

DISTRICT.	1904.			1905.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Loralai . .	...	...	...	1	20	Coal.
TOTAL .	0	...	...	1	...	...
Mining Leases.						
Quetta-Pishin .	1	660	Chromite .	2	120	Chromite and coal.
Zhob . .	6	160	Do. .	2	160	Chromite.
TOTAL .	7	...	...	4	...	...

Bengal.

The minerals produced in Bengal are chiefly coal, of which about 86 per cent. of the Indian output was raised in the province, iron-ore, used at the Barákar Iron and Steel Works, amounting to 95 per cent. of the total, mica, and saltpetre. The mica now raised is of very inferior quality, mainly obtained from the refuse heaps of the older workings, and its value has consequently fallen very greatly. The amount of saltpetre produced in Behar increased very largely during the year. A serious attempt is being made to ascertain by borings the value of the copper-ore belt in Singhbhum with a view to utilizing the sulphides in connection with the waste products from the iron works which are about to be established at Sini on the Bengal-Nagpur Railway.

Table 17.—*Prospecting and Mining Leases granted in Bengal during 1904 and 1905.*

District.	1904.			1905.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Darjeeling .	...	...	...	1	510	Any mineral, especially copper-ores.
Gaya . .	1	15	Mica . .	...	...	...
Mourbhanj .	...	...	...	1	12,800	Iron-ores.
Singhbhum .	2	14,080	Manganese-ore.	...	...	...
TOTAL .	3	...	...	2	...	...
Mining Leases.						
Gaya . .	1	1,557	Mica . .	...	...	...
Mánbhum .	1	2,165	Coal . .	...	...	...
Sonthal Parganas.	3	3	Do. . .	...	...	...
TOTAL . .	5	...	...	0	...	...

Bombay.

A considerable amount of prospecting is going on in the Bombay Presidency, especially for gold and manganese. The bauxite deposits contained in the laterite are also beginning to attract attention. One of the gold mines in Dhárwar, the Dhárwar Reefs Company's mine, produced 93 oz. of gold, valued at £320.

TABLE 18.—*Prospecting and Mining Licenses granted in Bombay during 1904 and 1905.*

District.	1904.			1905.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
			Prospecting Licenses.			
Belgaum .	...	...	...	2	22,997·12	Manganese.
Dhárwar .	8	3,720	Gold . .	7	5,177	Gold and manganese.
Kanara . .	...	...	...	1	4,992	Manganese.
Panch Mahals .	...	...	...	1	706·19	Do.
Satara . .	1	...	Manganese, copper, ochre, quicksilver.	1	1,280	Aluminium, bauxite, and other minerals.
TOTAL .	9	...	...	12	...	...
			Mining Leases.			
Belgaum .	...	...	...	1	...	Coal and manganese.
Dhárwar .	2	2,073	Gold . .	...	...	...
TOTAL .	2	...	...	1	...	...

Besides these, five exploring licenses were granted covering 185,937 acres.

Burma.

Prospecting operations are still being actively pursued in Burma, the number of licenses issued during the year being 25. Sixteen exploring licenses were also granted, some of them covering very large tracts of country. The output of petroleum was again the highest recorded, amounting to over 144 million gallons. Rubies are now only mined in the Mogôk area, and the outturn was practically the same as in 1904. Another gold dredger was placed on the Irrawaddi during the year, and the quantity of gold obtained rose from 216 oz. in 1904 to 620 oz. in 1905. The continued success of this enterprise has led to active prospecting in other directions, and a dredger has been set to work on the Namma river, a tributary of the Salween in the Northern Shan States. No coal was extracted anywhere in the province, the mines in the Shwebo district having been closed, but prospecting for coal is being carried on in the Chindwin district. The result of the examination of the Tertiary coalfields of the Northern Shan States has been disappointing, as the quality of the coal was found to be very poor. Reports on these coalfields will be found in *Records, Geological Survey of India*, Vol. XXXIII, Pt. 2.

TABLE 19.—*Prospecting and Mining Licenses granted in Burma during the years 1904 and 1905.*

DISTRICT.	1904.			1905.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
			Prospecting Licenses.			
Akyab . .	...	...	...	1	255·56	Coal.
Bhamo . .	...	...	...	1	18	Tourmaline.
Kathá . .	2	1,920	Gold .	1	1,350·40	Coal.
Lower Chindwin	1	1,344	Copper, gold, and other minerals.	1	12,800	Petroleum.
Magwé . .	...	...	...	1	3,200	Do.
Mandalay .	1	237	Iron-ore .	...	...	...
Do. .	1	160	Silver and other metalliferous minerals.	...	...	...
Mergui . .	1	640	Tin and other minerals.	3	2,256·68	Tin and other minerals.
Do. . .	2	12,800	Galena .	...	...	...
Myingyán .	2	7,040	Petroleum .	5	17,248	Petroleum.
Carried over .	10	...	...	13	...	

TABLE 19.—*Prospecting and Mining Licenses granted in Burma during the years 1904 and 1905*—contd.

DISTRICT.	1904.			1905.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Minerals.
Prospecting Licenses—*contd.*						
Brought forward	10	...	...	13	...	...
Northern Shan States.	2	5,760	Various minerals.	3	15,795·2	Gold, silver, and other minerals.
Do. .	1	2,240	Gold . .	...	...	...
Pakôkku .	4	5,120	Petroleum .	...	...	...
Prome . .	1	2,560	Do. .	1	2,560	Petroleum.
Shwebo . .	1	1,802	Coal . .	1	205·45	Gold, silver, and rubies.
Tavoy . .	3	227,744	Gold, silver, tin, etc.	1	224,000	Gold, silver, tin, etc.
Thayetmyo .	3	20,538	Petroleum .	1	100	Coal.
Do. .	1	100	Coal . .	1	6,400	Petroleum.
Upper Chindwin	...	...	...	1	640	Copper.
Do. .	...	...	...	2	800	Coal.
Yamèthin .	1	3,200	Tin and bismuth.	1	2,560	Tin and wolfram.
TOTAL .	27	...	...	25	...	...
Mining Leases.						
Mandalay .	...	...	...	1	272·2	Precious stones and marble.
Northern Shan States.	...	...	...	1	2,457·60	Gold.
Ruby Mines .	1	320	Graphite .	...	...	...
TOTAL .	1	...	...	2	...	...

Central Provinces.

The number of prospecting licenses issued during the year increased from 21 to 31. Manganese takes the most important place among the minerals now raised in the province, and owing to the unsettled state of Southern Russia the demand for the ore and consequently the price has increased. The mine-owners say that the carting charges incurred are becoming heavier every year and that railways are much wanted to open up the country. The coal mine at Warora in the Chánda district, which has been working since 1873 and has produced 3,053,893 tons of coal, has been abandoned, owing to the collapse of the workings, and the machinery is being removed to Bellarpur.

TABLE 20.—*Prospecting and Mining Licenses granted in the Central Provinces during 1904 and 1905.*

DISTRICT.	1904.			1905.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
			Prospecting Licenses.			
Bálaghát	1	134	Manganese	2	458	Manganese.
Bhandára	...	...	...	4	12,099	Do.
Do.	...	...	...	1	52	Asbestos.
Biláspur	1	3,216	Limestone	...	...	...
Chánda	1	131,200	Iron-ore	2	12,932	Coal.
Do.	4	29,969	Coal	...	...	...
Chhindwara	2	8,817	Manganese	8	50,036	Coal.
Do.	...	...	...	6	8,260	Manganese.
Hoshangabád	1	263	Lead, silver, and copper.	...	...	...
Carried over	10	...	...	23	...	

TABLE 20.—*Prospecting and Mining Licenses granted in the Central Provinces during 1904 and 1905*—contd.

DISTRICT.	1904.			1905.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses—*contd.*						
Brought forward	10	...	...	23	...	
Jubbulpore .	1	4,824	All minerals .	1	13,137	Iron and manganese.
Do. .	1	3,777	Iron and manganese.	3	11,403	Gold, silver, etc.
Do. .	1	1,023	Coal . .	1	447	Talc or soap-stone and dolomite.
Nágpur . .	5	509	Manganese .	1	2,287	Manganese.
Narsinghpur .	...	...	...	1	76	Gold, silver, etc.
Raipur . .	1	129,920	Iron-ore .	...	...	...
Sambalpur .	1	9,753	Coal . .	1	2,037·11	Gold, silver, etc.
Do. .	1	3,334	Limestone .	...	...	...
TOTAL .	21	...	...	31	...	...
Mining Leases.						
Bhandára .	...	...	...	1	222	Manganese.
Chhindwara .	1	54	Manganese .	1	3,827	Do.
Jubbulpore .	...	...	...	1	9	Ironstone.
Nágpur . .	1	150	Manganese .	2	126·47	Manganese.
Raipur . .	1	206	Iron-ore .	...	...	...
TOTAL .	3	...	...		...	...

In addition 17 exploring licenses were granted.

Eastern Bengal and Assam.

Very little activity is being shown in this province, as far as prospecting for minerals is concerned. Only one prospecting license was issued during the year, and no mining lease. The most important minerals raised are the Tertiary coal and petroleum in South Lakhimpur district, and neither of these shows much sign of expansion. The output of limestone from the southern slopes of the Khasi and Jaintia Hills was not so large as in the previous year owing, it is said, to depression of the market in Calcutta, and lack of facilities for transport.

TABLE 21.—*Prospecting Licenses granted in Eastern Bengal and Assam during 1904 and 1905.*

DISTRICT.	1904.			1905.		
	No.	Area.	Mineral.	No.	Area.	Mineral.
Cachar . .	1	1,280	Coal and petroleum.	...	...	...
Do. . .	4	284,800	Petroleum .	...	...	...
Khasi and Jaintia Hills.	...	...	...	1	640	Coal and oil.
Lakhimpur .	1	...	Gold . .	...	...	...
TOTAL .	6	...	...	1	...	...

Madras.

The number of prospecting licenses issued during the year was just doubled, and no less than 16 mining leases were granted in the Nellore district for mica-mining. Six exploring licenses were also granted for various minerals. The value of the graphite produced in Travancore was about the same as in the previous year, though about 1,000 tons less was raised. The corundum industry appears to have quite died out so far as present output is concerned, but some prospecting is still going on, and one mining lease for this mineral was granted.

TABLE 22.—*Prospecting and Mining Licenses granted in Madras during 1904 and 1905.*

DISTRICT.	1904. No.	1904. Area. Acres.	1904. Mineral.	1905. No.	1905. Area. Acres.	1905. Mineral.
Prospecting Licenses.						
Anantapur	...	...	...	4	3,072	Gold.
Belláry	1	1,920	Gold	1	143·46	Do.
Do.	...	..	..	1	43·76	Manganese.
Chingleput	1	11	All minerals	1	6,835·20	Coal, etc.
Coimbatore	1	800	Gold and copper.	5	138	Corundum.
Do	3	2,290	Gold	2	530	Gold.
Guntur	...	...	...	1	720	Copper.
Nellore	8	392	Mica	15	578·55	Mica.
Nilgiris	1	29	Gold	1	103·85	Gold.
TOTAL	15	.	..	31	...	...
Mining Leases						
Nellore	13	897	Mica	16	653·26	Mica.
North Arcot	...	...	..	1	10·86	Corundum.
TOTAL	13	...	...	17	..	.

Punjab.

Prospecting during the year was confined to coal in the Attock and Shahpur districts. A mining lease for stibnite and galena in the Kángra district, near the Shigri glacier, was taken out in 1904, but there does not seem to be any outturn from the mine as yet. The petroleum industry in this province is at a very low ebb and is confined to skimming off the accumulations of oil from small natural springs.

TABLE 23.—*Prospecting and Mining Licenses granted in the Punjab during 1904 and 1905.*

DISTRICT.	1904.			1905.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Attock . .	...	...	...	3	1,078·75	Coal.
Jhelum . .	7	13	Coal . .	...	...	...
Shahpur . .	...	...	...	2	670	Coal.
TOTAL .	7	..	...	5	...	...
Mining Leases.						
Kángra . .	1	·320	Stibnite and galena.	...	...	...
Shahpur . .	...	...	...	1	1,737	Coal.
TOTAL .	1	...	...	1	...	...

Rajputana. Prospecting for mica and asbestos is still going on in Ajmer-Merwára. No fresh licenses were issued during the year.

United Provinces. The principal mineral industry in the United Provinces is the extraction of building stone in the Mirzapur district, and of slate along the southern face of the Himalayas. Prospecting operations for copper and asbestos are being carried on in Kumaon and Garhwal.

TABLE 24.—*Prospecting and Mining Licenses granted in the United Provinces during 1904 and 1905.*

DISTRICT.	1904.			1905.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Almora . .	2	2,075	Copper . .	2	2,075·53	Copper.
Garhwál . .	...	...	...	4	3,195·70	Do.
Do. . .	...	...	...	1	1	Asbestos.
TOTAL .	2	...	...	7	...	...
Mining Lease.						
Almora . .	1	40	Copper . .	...	...	
TOTAL .	1	...	...	0	...	...

Number of mineral concessions granted.

The total number of concessions granted during the year was 189, including 44 exploring licenses. This is the highest number on record, showing an advance on 1904 of 38. The numbers for the last ten years are shown in table 25.

TABLE 25.—*Number of Licenses issued for the ten years 1896 to 1905.*

YEAR.	Mining and Prospecting Licenses.	Exploring Licenses.	TOTAL.
1896	80	1	81
1897	52	4	56
1898	85	1	86
1899	47	13	60
1900	61	11	72
1901	89	15	104
1902	89	16	105
1903	84	16	100
1904	125	26	151
1905	145	44	189

The names of those who have been granted concessions, together with the dates and periods of the licenses held, are enumerated in Appendix A.

APPENDIX A.

Statement showing the names of those who have been granted concessions, with dates and periods of licenses.

Province.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
BALUCHISTAN.	Loralai	(1) Messrs. Abdulla Asghar Ali & Co.	Coal	Prospecting license.	20	10th January 1905.	1 year.
	Quetta, Pishin.	(2) Mr. C. R. Lindsay	Chromite	Mining lease.	80	16th March 1905.	30 years.
	Do.	(3) Messrs. Allibhoy & Brothers.	Coal	Do.	40	10th November 1905.	Do.
	Zhob	(4) Mr. C. R. Lindsay	Chromite	Do.	80	16th March 1905.	Do.
	Do.	(5) Ditto	Do.	Do.	80	30th September 1905.	Do.
BENGAL.	Darjeeling.	(6) H. M. Lemnas and A. M. Lemnas.	Any minerals, metals, precious stones, especially copper ore.	Not stated.	510	21st October 1905.	6 months.
	Mohurbhanj	(7) Messrs. Tata & Sons	Iron	Prospecting license.	12,800	26th September 1905.	3 years.
BOMBAY.	Belgaum	(8) Messrs. Jambon & Co., Calcutta.	Manganese	Exploring license.	about 179,200	21st June 1905.	1 year.
	Do.	(9) Mr. Tardivel, Agent for Messrs. Jambon & Co.	Do.	Prospecting license.	2,254·7	3rd May 1905.	Do.
	Do.	(10) Mr. C. P. Boyce	Manganese ore	Do.	450·12	11th September 1905.	Do.
	Do.	(11) Ditto	Other Minerals	Exploring license.	702·12	Do.	Do.
	Do.	(12) Messrs. Haji Ismail Mahomed Kulli Mirza Bagdadi.	Coal and Manganese.	Mining lease.	...	...	...
	Dharwar	(13) Mr. C. G. Huddleston	Manganese	Prospecting license.	1,395·38	3rd March 1905.	1 year.

Province.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
BOMBAY—*contd.*	Dharwar .	(14) Mr. W. W. Coen .	Gold . .	Prospecting license.	635·39	1st February 1905.	1 year.
	Do. .	(15) Messrs. Shaw Wallace & Co.	Manganese .	Do.	212·22	4th April 1905.	Do.
	Do. .	(16) Mr. W. W. Coen .	Gold . .	Exploring license.	3,843·18	27th April 1905.	Do.
	Do. .	(17) Mr. A. M. Gowsmith (deceased); Administrator Mr. Patrick Gow.	Do. . .	Prospecting license.	939·34	10th August 1905.	Do.
	Do. .	(18) Mr. E. D. Puzey .	Do. . .	Do.	547·18	27th July 1905.	Do.
	Do. .	(19) Mr. C. G. Huddleston	Do. . .	Do.	393·24	3rd July 1905.	Do.
	Do. .	(20) Mr. C. P. Boyce .	Do. . .	Do.	1,054·28	19th July 1905.	Do.
	Do. .	(21) Mr. W. W. Coen .	Do. . .	Exploring license.	472·12	16th November 1905.	Do.
	Do. .	(22) Mr. W. W. Coen .	Do. . .	Do.	1,720·21	Do.	Do.
	Kanara .	(23) Mr. Patrick Gow .	Manganese .	Prospecting license.	4,992	8th March 1905.	Do.
	Panch Mahals.	(24) Mr. F. A. H. East .	Do. .	Do.	706·19	5th July 1905.	Do.
	Satara .	(25) Mr. C. H. B. Forbes .	Aluminium, bauxite, red ochre, copper, manganese, cinnabar and quick silver.	Do.	1,280	22nd October 1905.	Do.
BURMA.	Akyab .	(26) Thu Taw U and Shwe Min.	Coal . .	Do.	255·56	17th October 1905.	Do.
	Bhamo .	(27) Hsam Hline U (3) .	Tourmaline .	Exploring license.	18	4th July 1905.	Do.
	Do. .	(28) Maung San Wa U (2)	Do. .	Do.	6,400	11th July 1905.	Do.
	Do. .	(29) Hsam Hline U (3) .	Do. .	Prospecting license.	18	12th September 1905.	Do.
	Do.	(30) Min Ngin U (1) .	Minerals of every description.	Exploring license.	23,680	15th September 1905.	Do.

Province.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
BURMA—*contd.*	Bhamo	(31) Maung Chit U (3)	Minerals of every description.	Exploring license.	3,840	27th September 1905.	1 year.
	Henzada	(32) Mr. H. E. Rooke	Coal	Do.	165,888	2nd August 1905.	Do.
	Katha	(33) Messrs. P. N. Stathacopulos and E. P. Echlin.	Do.	Prospecting license.	1,350'40	12th April 1905.	Do.
	Lower Chindwin.	(34) Messrs. Finlay Fleming & Co., Agents for the Burma Oil Co.	Petroleum	Do.	12,800	8th April 1905.	Do.
	Magwe	(35) Ditto	Do.	Do.	3,200	27th April 1905.	Do.
	Mandalay	(36) Messrs. Sarkies Bros.	Precious Stones and Marble.	Mining lease.	2,2'2*	1st March 1905.	30 years.
	Mergui	(37) Mr. A. B. Snow for Burma Development Syndicate.	Tin and other minerals.	Prospecting license.	1905	13th March 1905.	1 year.
	Do.	(38) Messrs. J. Kinloch and J. Eglinton.	Do.	Do.	105'24	14th March 1905.	Do.
	Do.	(39) Lieut.-Col. K. M. Foss for Golden Stream Co., Ld.	Coal, gold, iron and tin.	Do.	246'61	6th January 1905.	Do.
	Myingyan	(40) Messrs. Finlay Fleming & Co., Agents for the Burma Oil Co., Ld.	Petroleum	Do.	6,400	10th May 1905.	Do.
	Do.	(41) Messrs. George Gillespie & Co., Agents for the Rangoon Oil Co., Ld.	Do.	Do.	640	Do.	Do.
	Do.	(42) Messrs. Finlay Fleming & Co., Agents for the Burma Oil Co., Ld.	Do.	Do.	3,504	4th October 1905.	Do.
	Do.	(43) Ditto	Do.	Do.	3,200	15th September 1904.	Do.
	Do.	(44) Ditto	Do.	Do.	3,504	4th October 1904.	Do.
	Northern Shan States.	(45) Mr. E. R. Kindersley.	Gold, silver, copper, lead and zinc.	Do.	10,240	16th February 1905.	Do.
	Do.	(46) Messrs. Diekmann Bros. & Co., Ld.	Gold	Mining lease.	2,457'60	9th January 1905.	30 years.

* At Sagyin Hills.

Province.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
BURMA—*contd.*	Northern Shan States.	(47) Messrs. Diekmann Bros. & Co., Ld.	Gold, silver and other minerals.	Prospecting license.	2,560	18th March 1905.	1 year.
	Do.	(48) Burma Prospecting Syndicate, Ld.	Do.	Do.	2,995·20	22nd April 1905.	Do.
	Pakokku	(49) Maung Po Gon	Petroleum	Exploring license.	6,400	8th July 1905.	Do.
	Do.	(50) Maung Kun and Maung Tun Fin Tun Hla.	Do.	Do.	3,200	Do.	Do.
	Do.	(51) Mung Mo Sin	Do.	Do. (renewal)	Unknown	5th August 1905.	Do.
	Do.	(52) Maung Kun	Do.	Do.	12,800	8th July 1905.	Do.
	Do.	(53) Maung Maung	Do.	Do.	*	8th February 1905.	Do.
	Do.	(54) Maung Po Sin	Do.	Do.	†	Do.	Do.
	Prome	(55) Messrs. Finlay Fleming & Co., Agents for the Burma Oil Co., Ld.	Do.	Prospecting license.	2,560	23rd July 1905.	Do.
	Sagaing	(56) Mr. C. E. Cardew, Loco. and Carriage Superintendent, Burma Railways Company, Limited (Public carriers).	Coal	Exploring license.	427,520	1st April 1905.	Do.
	Shwebo	(57) Mrs. Mary Vertannes	Gold, silver and rubies.	Prospecting license.	205·45	14th August 1905.	Do.
	Southern Shan States.	(58) Lim Chin Tsong, Tan Soon Ee, and four others.	Metals and minerals.	Exploring license.	24,634,240	28th December 1905.	Do.
	Do.	(59) Abdul Rahman	Precious stones	Do.	190,080	12th December 1905.	Do.
	Do. (Myelat and Yawnghwe States).	(60) Saw Nyun	Ore and precious stones.	Do.	All unoccupied areas in the two States.	4th June 1905.	Do.

* Description of land—Taungson hills in Myaing township bounded as follows:—North by Balin village, South by Taungyo village, East by Boungbin village, West by Nat Hteik hill.

† Zipagan and Kyauknyo hills bounded as follows:—North by Myaing stream, South by Myotha village, East by cart road, West by Chauktaung village.

Province.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
BURMA—*concld.*	Tavoy .	(61) Mr. G. R. Gilfillan for the Golden Stream Syndicate.	Gold, silver, tin, copper, coal, plumbago and precious stones.	Prospecting license.	224,000	20th September 1905.	1 year.
	Thayetmyo	(62) Gulaparaik Mahadeo	Coal . .	Do.	100	10th June 1905.	Do.
	Do. .	(63) Messrs. Finlay Fleming & Co.	Petroleum .	Do.	6,400	18th August 1905.	Do.
	Upper Chindwin.	(64) The Burma Mines Development and Agency, Limited.	Copper . .	Do.	640	28th November 1905.	Do.
	Do. .	(65) Ditto . .	Coal . .	Do.	160	Do.	Do.
	Do. .	(66) Mr. M. F. Kindersley	Do. . .	Do.	640	17th May 1905.	Do.
	Do.	(67) Mr. W. Macdonald .	Gold and other minerals.	Exploring license.	232,320	1st July 1905.	Do.
	Yamethin .	(68) Mr. T. F. Francis .	Tin and Wolfram.	Prospecting license.	2,560	6th March 1905.	Do.
CENTRAL PROVINCES.	Balaghat .	(69) Messrs. P. C. Dutt and Burn & Co.	Manganese .	Do.	324	10th October 1905.	Do.
	Do. .	(70) Ditto . .	Bauxite . .	Exploring license.	26,315	12th October 1905.	Do.
	Do. .	(71) Ditto . .	Manganese .	Do.	13,525	16th November 1905.	Do.
	Do. .	(72) Ditto . .	Do. .	Prospecting license.	134	Do.	Do.
	Do. .	(73) Messrs. Jessop & Co.	Do. .	Exploring license.	21,968	25th February 1905.	Do.
	Bhandara .	(74) Mr. D Laxminarain .	Do. .	Prospecting license.	537	16th November 1905.	Do.
	Do. .	(75) Messrs. Ratanchand Keshrichand Chullaney and Sons.	Asbestos . .	Do.	52	21st February 1905.	Do.
	Do. .	(76) The Central India Mining Co.	Manganese .	Mining lease.	222	24th March 1905.	30 years.

Province.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
CENTRAL PROVINCES—*contd.*	Bhandara .	(77) Messrs. Jessop & Co.	Manganese .	Prospecting license.	8,832	16th December 1904.	1 year.
	Do. .	(78) The Central India Mining Co.	Do. .	Do.	2,382	28th January 1905.	Do.
	Do. .	(79) Ditto .	Do. .	Do.	348	25th April 1905.	Do.
	Chanda .	(80) Messrs. Parry & Co. .	Coal . .	Do.	5,931	21st December 1905.	Do.
	Do. .	(81) Ditto .	Do. . .	Do.	7,001	1st December 1905.	Do.
	Chhindwara	(82) Messrs. Shaw Wallace & Co.	Do. . .	Mining lease.	3,827	8th December 1905.	30 years.
	Do. .	(83) Rai Sahib Mathura Prasad and Motilal.	Do. . .	Prospecting license.	16,522	24th November 1905.	1 year.
	Do. .	(84) Messrs. Ratanchand Keshrichand Chullaney and Sons.	Do. .	Do. .	4,348	18th October 1905.	Do.
	Do. .	(85) Ditto .	Minerals of all descriptions.	Exploring license.	25,215·24	1st September 1905.	Do.
	Do. .	(86) Mr. Tikamdas Cooverjee.	Coal . .	Prospecting license.	9,189·95	25th September 1905.	Do.
	Do. .	(87) Rai Sahib Mathura Prasad and Motilal.	Manganese .	Do. .	19	13th February 1905.	Do.
	Do. .	(88) Ditto .	Do. .	Do. .	150	Do. .	Do.
	Do. .	(89) Ditto .	Do. .	Do. .	195	31st March 1905.	Do.
	Do. .	(90) Ditto .	Do. .	Do. .	129	13th February 1905.	Do.
	Do. .	(91) Ditto .	Do. .	Do. .	72	Do. .	Do.
	Do. .	(92) Messrs. Macbeth Brothers & Co.	Coal . .	Do. .	1,060	29th March 1905.	Do.
	Do. .	(93) Messrs. Bird & Co. .	Do. . .	Do. .	2,157	18th March 1905.	Do.
	Do. .	(94) Messrs. Gowsmith Dundas Whiffin & Co. .	Manganese .	Do. .	7,695	25th March 1905.	Do.
	Do. .	(95) Messrs. Ratanchand Keshrichand & Sons.	Coal . .	Do. .	1,516	11th May 1905.	Do.
	Do. .	(96) Messrs. Shaw Wallace & Co.	Do. . .	Do. .	1,011	26th April 1905.	Do.

Province.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
CENTRAL PROVINCES—*contd.*	Chindwara	(97) Messrs. Macbeth Brothers & Co.	Coal . .	Prospecting license.	5,232	17th June 1905.	1 year.
	Jubbulpore.	(98) Messrs. Kettlewell Bullen & Co., Agents to the East India Iron and Steel Syndicate.	Iron and Manganese.	Do. .	13,137	3rd October 1905.	Do.
	Do. .	(99) Mr. Sherish Chunder Roy Chowdhry and the firm of Kanhaiyalal Govind Dass.	Gold, silver, copper and lead.	Exploring license.	5,269	4th December 1905.	Do.
	Do. .	(100) Messrs. H. F. Cook and Son.	Gold, silver, copper, zinc, lead, titanium, tungsten, tin, uranium and platinium.	Do.	3,442	5th November 1905.	Do.
	Do.	(101) Mr. P. C. Dutt and Burn & Bo.	Gold, silver, copper, lead, arsenic, zinc, iron, manganese, limestone, dolomite, barytes, tin, and antimony.	Prospecting license.	2,788·25	14th September 1905.	Do.
	Do. .	(102) Jubbulpore Prospecting Syndicate.	Gold, silver, lead, copper, zinc, tin, antimony and barytes.	Exploring license.	3,165·95	5th August 1905.	Do.
	Do. .	(103) Seth Jiwan Dass .	Manganese, coal, jasper, clay, copper, mineral oil, tin, lead, gold and silver.	Do.	5,156·18	25th July 1905.	Do.
	Do. .	(104) Raja Gokul Dass, Rai Bahadur Ballab Dass and Seth Jiwan Dass.	Do. .	Do.	2,414·06	25th July 1905.	Do.
	Do. .	(105) Messrs. Burn & Co. and P. C. Dutt.	Gold, silver, copper lead, platinum, bismuth, cobalt, nickel, zinc, antimony, arsenic, heavy spar, limestone, marble, coal, graphite, corundum, tin, fluor spar, felspar, soapstone, mercury, iron and manganese.	Prospecting license.	4,823·65	5th July 1905.	2 years.

Province.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
CENTRAL PROVINCES—*contd.*	Jubbulpore	(106) Mr. Sherish Chunder Roy Chowdhry.	Gold, silver, copper and lead.	Exploring license.	2,691·95	17th August 1905.	1 year.
	Do.	(107) Mr. R. Oates	Coal	Do.	4,063·09	4th September 1905.	Do.
	Do.	(108) Messrs. Jiwan Chander Mukerji and Krishto Dass Ghose.	Gold, silver, copper and lead.	Do.	3,868	14th April 1905.	Do.
	Do.	(109) Mr. P. C. Dutt	Copper, silver, lead, iron, manganese, limestone and barytes.	Do.	9,151	23rd June 1905.	Do.
	Do.	(110) Messrs. Olpherts & Co.	Ironstone	Mining lease.	9	1st July 1904.	10 years
	Do.	(111) Mr. P. C. Dutt	Talc or soap stone and dolomite.	Prospecting license.	447	14th February 1905.	1 year
	Do.	(112) Jubbulpore Prospecting Syndicate.	Gold, silver, copper, lead, antimony, arsenic, barytes, dolomite, limestone, zinc and tin.	Do.	3,791	22nd February 1905.	Do
	Do.	(113) Mr. P. C. Dutt	Ores of aluminium such as bauxite.	Exploring license.	4,953	30th January 1905.	Do.
	Do.	(114) Raja Gokul Dass, Rai Bahadur Ballab Dass and Seth Jiwan Dass.	Gold, silver, copper, lead, tin, coal and manganese.	Do.	702	23rd March 1905.	Do.
	Nagpur	(115) The Central India Mining Co.	Manganese	Mining lease.	74	17th January 1905.	30 year
	Do.	(116) Ditto	Do.	Prospecting license.	2,287	Do.	1 year.
	Do.	(117) Central Provinces Prospecting Syndicate.	Do.	Mining lease.	52·47	1st April 1906.	30 years
	Narsinghpur.	(118) Mr. P. C. Dutt for the Jubbulpore Prospecting Syndicate.	Gold, silver, copper, lead, arsenic, zinc, and antimony.	Prospecting license.	76	8th July 1905.	1 year.
	Sambalpur	(119) Jubbulpore Prospecting Syndicate.	Gold, copper, silver, lead, zinc, tin, barytes, and nickel.	Exploring license.	{ 2,037 / 1,308 }	6th April 1905.	Do.

Province.	District	Grantee.	Mineral.	Nature of grant.	Area in acres	Date of commencement.	Term.
CENTRAL PROVINCES—*concld.*	Sambalpur	(120) Mr. P. C. Dutt for Jubbulpore Prospecting Syndicate.	Gold, silver, copper, lead, zinc, antimony, barytes, limestone and tin.	Prospecting license.	2,037·11	29th July 1905.	1 year.
	Do.	(121) Jubbulpore Prospecting Syndicate.	Lead, silver gold and precious stones.	Exploring license.	4,246	25th July 1905.	Do.
E. B. AND ASSAM.	Khasi and Jaintia Hills.	(122) Mr. W. Garth .	Coal and oil .	Prospecting license.	640	11th July 1905.	Do.
MADRAS	Anantapur	(123) Mr. C. K. Martin .	Gold . .	Do. .	624·84	19th December 1906.	Do.
	Do. .	(124) Mr. R. H. Morris .	Do. . .	Do .	685·96	Do. .	Do.
	Do. .	(125) Ditto .	Do. .	Do. .	650·03	Do. .	Do.
	Do. .	(126) Ditto .	Do. . .	Do. .	1,111·12	Do. .	Do.
	Do. .	(127) Ditto .	Minerals of every description, and mineral oil.	Exploring license.	*	6th March 1905.	Do.
	Bellary .	(128) Capt. C. Rolleston .	Gold . .	Prospecting license.	143·36	4th July 1905.	Do.
	Do. .	(129) Mr. C. Jamben .	Manganese .	Do. .	43·76	23rd June 1905.	Do.
	Chingleput	(130) Messrs. Best & Co. .	Coal, mineral ores, and mineral oils.	Do. .	about 6835·20	12th March 1905.	Do.
	Coimbatore	(131) Govindji Odaji Sait .	Corundum .	Do. .	20·93	10th October 1905.	Do.
	Do. .	(132) Narayana Dass Odaji Sait.	Do. .	Do. .	3·52	8th August 1905.	Do.
	Do. .	(133) M. H. Gompertz .	Gold . .	Do. .	210	17th July 1905.	Do.
	Do. .	(134) Govindji Odaji Sait .	Corundum .	Do. .	17·17	3rd August 1905.	Do.
	Do. .	(135) Mr. F. E. Dunn .	Gold . .	Do. .	320	15th September 1905.	Do.
	Do. .	(136) Ditto .	Do. . .	Exploring license.	about 4,400	27th September 1905.	Do.
	Do. .	(137) Govindji Odaji Sait	Corundum .	Prospecting license.	86·45	15th May 1905.	Do.
	Do. .	(138) Ditto .	Do. .	Do. .	9·86	28th June 1905.	Do.

* Dharmavaram and Penukonda taluks.

Province.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
MADRAS—*contd.*	Godavari .	(139) Mrs. P. C. Puddephatt.	Coal, exclusive of dust, oil, gold or silver, iron, other metals, mica, corundum, phosphatic nodules, steatite, chromite, manganese, graphite and rock crystal.	Exploring license.	2,600*	4th July 1905, 12th July 1905.	1 year.
	Do. .	(140) Messrs. R. T. Menzies and S. D. Ware.	Do.	Do. .	31,413·50	7th July 1905.	Do.
	Guntur .	(141) Mr. E. D. Puzey .	Copper . .	Prospecting license.	720	21st September 1905.	Do.
	Do. .	(142) Shapoor Edoy Shapoor Dadi.	Certain valuable minerals.	Exploring license.	16,000	16th December 1905.	Do.
	Kistna .	(143) Mr. S D. Ware .	Coal and other minerals.	Do. .	18,445	30th September 1905.	Do.
	Nellore .	(144) R. Lakhminarasa Reddi.	Mica . .	Prospecting license.	20	15th September 1905.	Do.
	Do. .	(145) Ditto .	Do. . .	Do. .	30·8	Do.	Do.
	Do. .	(146) Mirza Zulficar Ali .	Do. . .	Patta-land mining.	2·83¼	27th September 1905.	20 years.
	Do. .	(147) R. Lakshminarasa Reddi.	Do. . .	Prospecting license.	37·45	18th November 1905.	1 year.
	Do. .	(148) Haji Muhammad Badsha Sahib & Co.	Do. . .	Mining lease.	9·65	26th September 1905.	30 years.
	Do. .	(149) P. Penchalareddi .	Do. . .	Do.	57·62	7th October 1905.	3 years.
	Do. .	(150) R. Rangaswami Rao	Do. . .	Do.	100·2	22nd September 1905.	Do.
	Do. .	(151) Y. Kalappachetti and S. Chinnachenchu Naidu.	Do. . .	Do.	14·96	28th August 1905.	30 years.
	Do. .	(152) M. Devarajulu Nayudu.	Do. . .	Do.	23	18th September 1905.	Do.
	Do. .	(153) R. V. Kuppuswami Aiyar.	Do. . .	Do.	13·38	10th November 1905.	Do.

* Approximate.

Province.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
MADRAS—*contd.*	Nellore .	(154) S. Venkatasubbayya	Mica . .	Mining lease.	15·4	19th July 1905.	30 years.
	Do. .	(155) I. Ramaswami Reddi	Do. . .	Prospecting license.	35·58	12th September 1905.	1 year.
	Do. .	(156) R. V. Kuppuswami Aiyar.	Do. . .	Mining lease.	42·46	7th July 1905.	30 years.
	Do. .	(157) G. Ramaswami Naidu & Son.	Do . .	Prospecting license.	45	11th August 1905.	1 year.
	Do. .	(158) A. Venkatachala Mudaliar.	Do. . .	Mining lease.	13·24	5th August 1905.	30 years.
	Do. .	(159) M. Devarajulu Naidu	Do. . .	Patta land mining.	2·50	12th August 1905.	20 years.
	Do. .	(160) K. Penchala Reddi .	Do. . .	Do. .	27·95	26th July 1905.	Do.
	Do. .	(161) R. V. Kuppuswami Aiyar.	Do. . .	Prospecting license.	26·66	20th July 1905.	1 year.
	Do. .	(162) Ditto .	Do. . .	Do. .	25·10	Do. .	Do.
	Do. .	(163) Ditto .	Do. . .	Patta land mining.	7·95	2nd September 1905.	20 years.
	Do. .	(164) Messrs. Gordon, Woodroffe & Co.	Do. . .	Mining lease.	16·85	3rd November 1903.	10 years.
	Do. .	(165) K. Venkatasubha Raju.	Do. . .	Do.	25·7	1st July 1904.	3 years.
	Do. .	(166) P. Venkatappa .	Do. . .	Prospecting license.	63·36	4th February 1905.	1 year.
	Do. .	(167) K. Adinarayana Reddi.	Do. . .	Do. .	16·20	24th February 1905.	Do.
	Do. .	(168) Ditto .	Do. . .	Do. .	19·8	Do. .	Do.
	Do. .	(169) G. Ramaswami Naidu and Sons.	Do. . .	Do. .	25·9	26th August 1905.	Do.
	Do. .	(170) Ditto .	Do. . .	Mining lease.	8·9	25th August 1903.	30 years.

Province.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
MADRAS—*concld.*	Nellore	(171) I. Ramaswami Reddi.	Mica	Prospecting license.*	47·90	8th January 1905.	1 year.
	Do.	(172) R. V. Kuppuswami Aiyer.	Do.	Do.	101·13	25th September 1904.	Do.
	Do.	(173) V. Annaji Rao	Do.	Do.*	72·89	12th May 1905.	Do.
	Do.	(174) Ditto	Do.	Do.*	10·69	Do.	Do.
	Nilgiris	(175) Mr. F. W. F. Fletcher.	Gold	Do.	103·85	10th May 1905.	Do.
	North Arcot	(176) Shaik Ali Sahib	Corundum	Mining lease.	10·86	1st January 1905.	5 years.
PUNJAB.	Attock	(177) Mehdi Shah of Mirza.	Coal†	Prospecting license.	290·5	24th February 1905.	1 year.
	Do.	(178) Ditto	Do.‡	Do.	71	7th February 1905.	Do.
	Do.	(179) Ditto	Do.§	Do.	717·25	7th March 1905.	Do.
	Shahpur	(180) Lala Bhagwan Das and Ram Das.	Do.	Mining lease.	1,737	15th January 1905.	15 years.
	Do.	(181) Malik Mohan Singh	Do.	Prospecting license.	124·61	1st May 1905.	1 year.
	Do.	(182) Lakshmi Singh and Dewa Singh.	Do.	Do.	545·43	5th June 1905.	Do.
UNITED PROVINCES.	Almora	(183) Mr. G. G. Anderson	Copper Ore	Do.	1,057·85	1st June 1905.	Do.
	Do.	(184) Mr. W. J. Burn	Do.	Do.	1,017·68	Do.	Do.
	Garhwal	(185) Mr. R. M. Nash	Do.	Do.	1,195·70	20th June 1905.	Do.
	Do.	(186) Ditto	Do.	Do.	2,000	14th July 1905.	Do.
	Do.	(187) Ditto	Do.	Do.	1,195·70	Renewed. 20th June 1904.	Do.
	Do.	(188) Ditto	Do.	Do.	2,000	Renewed. 14th July 1904.	Do.
	Do.	(189) Ditto	Asbestos	Do.	1	Renewed. 11th August 1904.	Do.

* Renewal.
† Coal mines at Mauza Surag Salar.
‡ Coal mines at Haji Shah.
§ Coal mines at Mauza Chhoi.

NUMMULITES DOUVILLEI, AN UNDESCRIBED SPECIES FROM KACHH WITH REMARKS ON THE ZONAL DISTRIBUTION OF INDIAN NUMMULITES. BY E. VREDENBURG, *Officiating Superintendent, Geological Survey of India.* (With Plate 8.)

INTRODUCTION.

DURING the months of July, August, and September 1905, I occupied my leisure moments in studying the nummulites preserved in the Geological Museum of Calcutta, many of which I collected during my surveys of Sind and Balúchistán. I wrote descriptions of all the forms that I identified, with the intention of publishing them in the "Palæontologia Indica," but a difficulty arose in connection with the illustration of this Memoir which has impeded its publication.

Amongst Wynne and Fedden's collections from Kachh, I noticed an interesting form which appears different from all those whose descriptions have been accessible to me. I take the present opportunity to give an account of it, and have appended a few remarks on the zonal distribution of the Indian nummulites, as this is of great importance for determining the age of the Indian Tertiaries.

DEFINITION.

Nummulites media vel major, lenticularis, depressa. Striæ reticulatæ, sæpe ab numerosis crassis punctis celatæ. Lamina spiralis tenuis. Gyri pauci, spira rapide increscens. Septa radiata, ad ultimi gyri superficiem conspicua. Loculi altitudinis duplicis quam latitudinis. Megasphæricus loculus, major.

DESCRIPTION.

I. Microspheric Form.

The dimensions measured upon various individuals are :—

Diameter in millimetres .	17	17	15·5	13·5	13·1	11	7
Thickness „ „ .	3·1	3	3·9	2	2·8	3	1·8

From the axis to the inner edge of the last whorl, the shape is that of a very depressed lens, beyond which the last convolution projects as a broad narrow flange, the actual margin being slightly thickened externally by the contained marginal chord. The margin sometimes exhibits broad sub-angular flexuosities similar to those observed in nummulites of the group of *N. Murchisoni*. When the specimens are adult and complete, an elbow-shaped bend of this sort indicates the final rapidly contracted whorl that closes the spire. This is especially conspicuous in some of the megaspheric individuals (Fig. 11). The position of the outermost septa is indicated externally by raised ribs on the flange-like surface of the last whorl. This peripheral portion carries no granulations, except, occasionally, some small ones situated along the projecting septal ribs, as is commonly seen in *Assilina* and *Operculina*. Within the inner margin of the last convolution, the granulations are closely packed all over the lenticular portion of the test. There is usually one pillar at the junction of each septal ridge with the marginal chord of the previous whorl. These pillars rise through the succeeding lamellæ and reach the outer surface in the form of granules. This may give rise, on the outer surface, to a spiral or concentric disposition of the granules, so that two or three whorls can sometimes be recognised at the surface, within the outermost whorl, very much as in an *Assilina* (Figs. 3, 5). Other pillars originate along the septa without any very definite order, and, on reaching the surface, assume the same size as those from the marginal chord, so that in most specimens, the spiral arrangement of the granules becomes too confused to be detected.

The septal filaments are fine, rather crooked, rather widely spaced, and are disposed in broad, irregular, concentric curves; they give off irregular branches which often anastomose with one another so as to form a loose network with large elongated meshes. The granulations are always situated on the filaments (Fig. 8*b*).

The equatorial section has a very remarkable appearance, and is more like that of an assiline than of a nummulite. Its main features are the regular thinness of the marginal chord, the rapidly increasing height of the convolutions, and the thinness, straightness, length, and radiating disposition of the septa. There are 10 whorls to a radius of 7 millimetres, the intervals between them increasing rapidly until near the edge where they become a little less. The broadest interval is between the 7th and 8th whorls. The outer 3·5 millimetres, that is, the outer half of the radius, consists of only three convolutions, the inner half, of the previous seven. The innermost convolutions are very minute. The width of the marginal chord, as seen in an equatorial section, is equal to one-third the height of the intervals, or less, and is very constant]; its course exhibits broad sinuosities, recalling those that characterise the species of the *N. Murchisoni* group. There are never any bifurcations. The septa are long, thin, quite straight, except where they curve backwards in the immediate neighbourhood of their junction with the succeeding turn of the marginal chord. It is only quite close to this contact that the two septal foliæ become separated, so that the superior posterior angle of the chambers, although very short, is quite distinct. For the same reason, it is only occasionally that extremely small depressed loculi occur between the diverging septal foliæ and the enveloping marginal chord; it is only in consequence of the fine state of preservation of the specimens that these small spaces are appreciable. The septa exhibit the unusual peculiarity of being often inclined slightly forward throughout the greatest portion of the spire, except in the innermost convolutions where they become truly normal to the previous whorl, or slightly inclined backwards as is usual in most nummulites and assilines. In adult specimens, the peripheral flattened whorl assumes a particularly remarkable appearance, for the septa become extremely inclined, the direction of inclination often remaining forward, while the curvature of their outer extremity is naturally in the opposite direction. (In the section represented in Fig. 7, the artist has shown the best preserved portion of the specimen in which the septa of the peripheral convolution are inclined backward. But the opposite direction is more usual.) The only other species in which I have observed septa distinctly inclined in front of the normal is the very operculiniform *Assilina tattaensis*, (d'Archiac and Haime's *Operculina tattaensis*,) in which, however, this tendency is by no means so frequent.

The spacing of the septa is very regular. Their number per quarter of a circumference is 11 at a radius of 3·8 millimetres, 13 at a radius of 4·6. The height of the chambers equals twice their depth.

In a transverse section, the lamellæ appear extremely thin, especially when compared with the marginal chord: on leaving the marginal chord, their thickness becomes at once extremely reduced and they remain very thin up to the axis. The interlamellary spaces are at least as broad as the thickness of the envelopes which they separate; these spaces are consequently very conspicuous in spite of the depressed shape of the test. The columns are very thick and numerous, and extend from layer to layer up to the outer surface of the test forming a succession of cones with their base turned outward. The transverse section of the chambers is of large size; its shape is that of a tall triangle on either side of whose base the chamber communicates with the interlamellary spaces. Owing to their good state of preservation, the specimens show very clearly the different constitution of the substance of the marginal chord, pillars, and vitreous layer from that of the perforated parts of the test. The vitreous layer seems to constitute a very thin extension of the marginal chord coating the opaque-white spiral lamella whose junction with the flint-like substance of the marginal chord is quite abrupt.

The outer peripheral portion of the marginal chord is very broad and is striated with numerous very fine regular grooves. The two deep furrows which, as is usual in nummulites, follow the junction of the grooved surface with the edge of the septal layers, are very conspicuous and regular, resembling the beautiful figure of d'Archiac and Haime's monograph which represents this structure in *N. planulatus* (Pl. IX, Fig. 7*h*). The numerous fine grooves of the marginal chord are visible even on the outermost whorl in portions that do not appear to have been protected by an external convolution. The minute branching canals described by Carpenter and by Carter as occurring within the marginal chord of nummulites and operculines are distinctly visible in equatorial sections of the present species.

All the foraminifera occurring in the same bed as these nummulites are very well preserved. The internal spaces of the test are never filled with calcite; not only are the chambers and interlamellary spaces empty in this nummulite and others such as *N. obtusus* occurring with it, but the envelopes have still retained their porous texture, and the specimens feel as light as a piece of wood or of cork. In many cases they are impregnated with bituminous matter, perhaps the remains of the original sarcode. It forms a black semi-fused coating in the interior of the chambers of specimens that have been artificially heated.

2. Megaspheric orm.

The following dimensions have been measured:—

Diameter in millimetres .	5·1	4·9	4·8	4·5	4·1
Thickness „ „ .	1·9	1·2	1·2	1·9	1·9

The shape, up to the inner edge of the last convolution, is sublenticular, sometimes fairly convex, at other times very much depressed; the last whorl constitutes a broad, thin, flange-shaped rim, slightly swollen at the rounded margin. The margin is circular or helicoidal, except in perfect specimens of adult individuals where the sudden contraction of the last whorl, in order to close the spire, gives a very peculiar elbow-like outline (fig. 11). The swollen lenticular portion of the test is covered with coarse granulations, or, rarely, is almost smooth. The septa of the last whorl form distinct radiating ridges, sometimes covered with small granulations gradually increasing in size as they recede from the margin. Except in unusually smooth specimens, there is always a coarse granule at the junction of each septum with the marginal chord of the previous whorl, and the spiral series thus formed may, occasionally, be recognised at the surface of the test throughout several convolutions. The septal filaments are radiating or slightly falciform. They are often almost obliterated by the coarse granulations. The combination of all these characters produces an appearance which is even more like that of an *Assilina* than in the case of the microspheric form.

There are three whorls to a radius of two millimetres, the intervals between them increasing rapidly, especially as regards the third interval. A fourth whorl closes the spire by means of the curious angular bend already mentioned, a feature that is frequently observed in nummulites that have a rapidly increasing spire. Owing to the small number of whorls combined with the rapid rate of increase of the intervals, the appearance of the equatorial section recalls that of an *Operculina*.

The marginal chord as seen in an equatorial section appears uniformly thin; its course remains remarkably smooth, the regularity of the curve being only interrupted, as already explained, by the final closing of the spire. Its thickness is equal to one-third or one-fourth of the height of the chambers.

The megasphere is large and spherical; it is followed by a very large crescentic or hemispherical chamber, the second serial chamber being also rounded and very large. The combination of these three innermost chambers has a very striking appearance. The total number of chambers in the first convolution is only six; fifteen chambers constitute the second convolution, twenty-four the third. In the second and third convolution, the shape of the septa and of the chambers becomes very similar to that of the microspheric form.

the chambers are sub-rectangular and twice as high as deep in the third convolution, the proportional height being a little less in the second. The septa, just as in the microspheric form, are very slender; they are very straight except where they bend backwards in the immediate neighbourhood of the enveloping marginal chord. They are either normal to the previous whorl or slightly inclined; the inclination may be either forward, as is often the case in the microspheric individuals, or backwards.

The transverse section shows very clearly the large size of the megasphere and also the large size and hemispherical shape of the first and second serial chambers. With the exception of the marginal chord, the envelopes appear everywhere very thin, just as much so in the neighbourhood of the marginal chord as at the axis. The width of the interlamellary spaces exceeds the thickness of the lamellæ even in the most flattened specimens. In transverse section, the chambers appear large, the columns thick and numerous. The shape of the test was practically the same at all stages of growth.

The large size of the megasphere is probably connected with the slenderness of the spiral lamella and the considerable development of the interlamellary spaces; it seems, from Lister's researches, that the size of the megasphere depends upon the total amount of sarcode in the microspheric form rather than the actual dimensions of the solid parts of the test. (*Proc. Roy. Soc.*, Ser. B, Vol. 76, p. 298.)

RELATION TO OTHER SPECIES.

This nummulite belongs to the group of *Nummulites lævigatus*, but its peculiarities are so pronounced that they seem sufficient to rank as specific distinctions. Externally it resembles d'Archiac and Haime's figure of *N. Defrancei* in the "Monographie," but the internal characters do not agree with those of that species as described and figured by them. The Middle Khirthar in Sind and Balúchistán contains a nummulite which closely agrees with the diagnosis of *N. Defancei* and which is a mere variety of *N. lævigatus* remarkable for its depressed shape and loose spire; its equatorial section somewhat recalling that of *N. irregularis* is quite different from that of *N. Douvillei*.

When attempting to work out geological problems in India, not only do we often meet with insuperable difficulties from the absence of specimens for comparison, but it is often impossible even to consult important publications on particular subjects. For instance, I have not been able to procure Tellini's monograph on the nummulites of the Maiella, the Gargano, and the Tremiti Islands (*Boll. Soc. Geol. Ital.*, Vol. IX) containing the description of *N. italicus*, one of the group of *N. lævigatus*, which is spoken of by Martelli, in his description of the eocene fossils from Spalato in Dalmatia, precisely in connection with *N. Defrancei.* (*Pal. Ital.*, Vol. VIII, p. 81.) Nevertheless, judging from Martelli's allusions to this species, and the photographs illustrating it, (loc. cit., Pl. VII, figs. 5, 6), it does not seem to correspond with the Indian fossil. There is little doubt, therefore, that the latter is an undescribed species which I would be glad to dedicate to the geologist whose brilliant researches on the subject of the Foraminifera have thrown so much light on the classification of the Tertiary System and thereby enabled us to attempt a correlation of the rocks of that age which occur in India.

GEOGRAPHICAL AND GEOLOGICAL DISTRIBUTION OF NUMMULITES DOUVILLEI.

This nummulite is only known, so far, from two localities in Kachh, labelled Lakhpat, and Noondatur, where they were collected by Wynne and Fedden.

The stratigraphy of the Tertiary zones in Kachh has not been elucidated in detail. But the species associated with *N. Douvillei* enable us to determine its geological horizon. These are *Nummulites lævigatus*, (a medium size form, strongly granulated, identical with *N. scaber* of the Paris basin,) and *N. gizehensis*, var. *obtusus* Sow.= *Champollioni* la H. The association of these species, and especially the presence of the one last-named which has a very limited vertical range, fixes this horizon as Middle Khirthar, that is the zone richest in species of nummulites.

ZONAL DISTRIBUTION OF INDIAN NUMMULITES.

The Indian nummulites occur in four successive geological series separated from one another by unconformities. The three older series constitute the Ranikot, the Laki, and the Khirthar of Western India. The lower division of the newer series is known as Nari, and contains the newest zones rich in large nummulites.

The Ranikot, including the oldest Tertiary beds of India, outcrops only over a comparatively small portion of Sind. It includes two sub-divisions, a lower one, mainly consisting of sandstones, with occasionally a bed of lignite, and an upper one consisting of limestones and shales. The Lower Ranikot contains no marine fossils, except a species of *Ostrea* occurring in great abundance in a littoral conglomerate at the very base of the series. The Upper Ranikot roughly corresponds in age with the London clay; the Lower Ranikot may be regarded therefore as the equivalent of the Woolwich and Reading beds. The Upper Ranikot is divided into four principal zones which are very distinctly demarcated by their fossils, especially the Echinoids. Nummulites have not been observed in the two lower zones. The uppermost zone contains *Nummulites planulatus.*[1] A small *Assilina*, probably referable to the form described by d'Archiac and Haime as *Nummulites miscella*, occupies the two upper zones.

The Ranikot rests with complete unconformity upon the Deccan Trap or the associated *Cardita Beaumonti* beds whose age is Mæstrichtian, perhaps reaching into Lower Danian. The gap between the Cretaceous and the Eocene is just as pronounced in India as in Europe.

Resting unconformably upon the Ranikot, is another nummulitic series of Lower Lutetian age, which was grouped by Blanford with the Khirthar in Sind, but subsequently separated in Balúchistán by Griesbach who called its most conspicuous member the "Alveolina limestone." The same distinction was recognised in Sind by Noetling and myself when we worked in that province at the beginning of the year 1900. Noetling has proposed for this series the name of "Laki" from the conspicuous Laki ridge which consists largely of the "Alveolina limestone."

Three divisions have been recognised in the Laki series. The lower division, which might be called the "Meting shales" after the name of a highly fossiliferous locality in Sind, contains *Nummulites atacicus* and a variety of *Assilina granulosa* which was referred to the genus *Operculina* by Carter and named *Operculina tattaensis* by d'Archiac and Haime. The middle division, constituting Griesbach's Alveolina limestone, contains *Assilina granulosa* type, *Nummulites*

[1] The microspheric individuals were referred to *N. irregularis* by Blanford, and the megaspheric ones to *N. Ramondi* by Rupert Jones and Fedden. (*Mem. Geol. Surv. Ind.*, Vol. XVII, pp. 40 and 198.) This is not the form referred to *N. irregularis* by Carter.

atacicus, and a variety of *N. irregularis* somewhat intermediate between *N. planulatus* and *N. irregularis* type. The upper sub-division, constituting Oldham's Ghazij beds of Balúchistán, contains *Nummulites atacicus*, *Assilina granulosa*, and in its upper layers a small variety of *A. exponens*.

The Laki series is the coal-bearing formation of Balúchistán and the Punjab. At the Dandot Colliery, the carbonaceous shaly layers at the roof of the coal are crowded with the megaspheric form of *A. granulosa* (*A. Leymeriei*). The Laki series corresponds with Zittel's Lybian in Egypt.

The nummulitic series succeeding the Laki is known as the Khirthar. Wherever the Laki and Khirthar are observed in direct superposition, they are unconformable to one another. In the Khirthar range, along the Sind-Balúchistán frontier, the Laki and Ranikot series are absent, the Khirthar resting directly on the Upper Cretaceous. Blanford has divided the series into two sub-divisions, the Lower and Upper Khirthar.

At the base of the Lower Khirthar is a black brecciated or conglomeratic limestone, largely developed in many parts of Balúchistán, containing *Assilina exponens*, *Nummulites irregularis*,[1] *N. lævigatus*, *N. perforatus* type and var. *obesus*. The overlying shales constituting the bulk of the Lower Khirthar, with an aggregate thickness that may amount to several thousand feet, are very unfossiliferous; occasionally there exist intercalated calcareous or arenaceous bands containing *Assilina exponens*, *Nummulites lævigatus*, and *N. perforatus*.

At the base of the Upper Khirthar are the horizons richest in nummulites. Two zones can be distinguished, a lower one, partly calcareous, but frequently containing shaly intercalations, and an upper one, mainly calcareous. The lower zone is characterised by *Assilina exponens* (several varieties), another *Assilina* related to *A. spira* which I have called *A. sufflata*,[2] *N. lævigatus*, *N. perforatus*

[1] This, or the Laki nummulite associated with *N. atacicus*, is the form identified by Carter as *N. irregularis*. *Ann. Mag. Nat. Hist.*, Vol. VIII, ser. 3, p. 376, 1861.

[2] This form has been erroneously referred by Blanford (*Mem. Geol. Surv. Ind.*, XVII, p. 10) to Carter's *Assilina obesa*. The latter is the megaspheric form (*A. mammillata*) of a gigantic *A. exponens*, Carter's var. *b.* (*Ann. Mag. Nat. Hist.*, Vol. VIII (3), p. 367.)

type and var. *obesus*, *N. discorbina*, *N. gizehensis*, the latter including the forms referred by d'Archiac and Haime to *N. obtusus*, *N. Vicaryi*, *N. Lyelli* type and variety *b*, and a Subathu form which seems to have been confounded by them with *N. Beaumonti*. This is the horizon of *N. Douvillei* in Kachh. The following horizon contains *Assilina exponens*, *A. spira*, *Nummulites Carteri* which is a large variety of *N. lævigatus* analogous probably with some of the forms ascribed in various countries to *N. complanatus* or *N. distans*, *N. Beaumonti*,[1] *N. Murchisoni* (similar to Fig. 3, Pl. IV of de la Harpe's "Nummulites de la Suisse"), *N. perforatus*, *N. discorbina*.

In most of the hill-ranges of Sind, excepting the Khirthar range, this horizon is immediately succeeded by the oligocene Nari. But in the Khirthar range, and in many parts of Balúchistán, there intervenes a vast thickness of enormously massive limestones which constitute the bulk of Oldham's Spintangi. They can be roughly divided into four zones, all of which contain nummulites, although it is not always easy to study them, owing to the extreme hardness of the limestones in which they are embedded. The lowermost zone, including somewhat over one-third of the total mass, contains *Assilina spira*, often of very large size, and *Nummulites perforatus*. In the following beds of about the same thickness, I have only found *N. perforatus*. The next horizon which is only occasionally developed at places where the limestone has preserved its maximum thickness, is often crowded with specimens, both megaspheric and microspheric, of only one species of nummulite, *N. complanatus*,[2] the largest of all the Indian nummulites.

[1] This is similar to the Egyptian form as described by la Harpe in the Monograph of the Nummulites from Egypt and the Lybian desert. (*Palæontographica*, Vol. XXX, 1883.) D'Archiac and Haime's diagnosis of *N. Beaumonti* seems based partly on the Egyptian fossil, and partly on immature specimens of a small race of *N. gizehensis* occurring at Subathu.

[2] The illustrations in d'Archiac and Haime's monograph which give the best idea of this form are Figs. 3 and 9, Pl. I, and Figs. 1, 2, 3, Pl. II. At a much lower horizon, *N. Carteri*, the large variety of *N. lævigatus*, frequently assumes a very similar appearance. In the form which I have referred to *N. complanatus* the septa are always much more numerous than in *N. Carteri*, and the general appearance much closer to that which characterises the nummulites of the group of *N. Murchisoni*. This characteristic appearance is quite independent of the great variations in the height and number of the whorls which one observes from one specimen to another.

Lastly, in the Mula Pass, there exists a horizon still higher than that of *N. complanatus*, but the limestone constituting it is so excessively compact that it is difficult to make out the characters of the nummulites which it contains. There is a strongly granulated species which may be *N. Brongniarti*, a striated species with somewhat numerous septa perhaps referable to *N. biarritzensis*, and a very small form, perhaps *N. variolarius*.

It is evident, from the composition of its nummulitic fauna, that the Khirthar corresponds with the bulk of the Middle Lutetian, the uppermost beds of the massive limestones representing the Upper Lutetian. The Khirthar series corresponds partly with Zittel's "Mokattam" in Egypt.

There is an unconformable break between the Khirthar and the succeeding formations, the interval representing a period of important orogenic movements. This gap corresponds chiefly with the Bartonian, typical representatives of which are not known in India. Two great Tertiary series are known in India, newer in age than the Khirthar. The newest constitutes the well-known Siwaliks, of Pontian and Pliocene age. The older series, including in one continuous sequence the Oligocene with the Lower and sometimes Middle Miocene, has received a great number of local appellations none of which have been applied to the group as a whole, except in Burma, where the entire series was designated by Theobald as the "Pegu group." Strata of the same age are locally known under the names of Dagshai, Kasauli, and Murree beds in the Himalayan region and the Punjab, Nari and Gáj in Sind, Kojak shales when they assume the flysch facies in Balúchistán,[1] Mekran beds in the district of that name. The latter name is the most comprehensive one for Western India. When Blanford first established this group, he was unable to ascertain, owing to the incomplete data then available, whether it is entirely newer than the Gáj of Sind, or corresponds partly with it. The surveys which I have lately completed have shown that the Mekran series includes beds both newer and of the same age as the Gáj of Sind, and also older ones, contemporaneous,

[1] In the absence of satisfactory evidence, the Kojak shales had hitherto been regarded as eocene. During my survey of the Mekran district, in January and February of the present year, I came across a number of fossiliferous localities containing oligocene species. These beds correspond therefore with the oligocene flysch of Europe.

therefore, with the underlying Nari. All these beds constitute a compact geological group, which, unless one extends to it the name of "Pegu series," may be known as the "Mekran series," including the Nari and Gáj of Sind, and some beds newer than the latter which may be called the Hingláj division after the mountain range of that name containing a thickness of some 4,000 feet of these newer beds. Over the greatest part of the Mekran district, and in many other parts of Balúchistán, the Nari and Gáj assume the flysch facies under which condition they constitute Griesbach's "Kojak series."

The Lower Nari beds are often crowded with nummulites. These usually belong to the species *N. intermedius* and *N. vascus*. In the Mula Pass, the lowermost beds consist of a hard limestone containing *N. intermedius* in company with a striated form, larger and more convex than *N. vascus* and with the septa more numerous. It is so completely embedded in the hard rock that I cannot identify it with certainty. It may be *N. contortus*. These beds are quite distinct from the compact limestones of the same neighbourhood already referred to as containing obscure nummulites of possibly Upper Lutetian age. The presence of *N. intermedius* and of *Clypeaster* in the limestone containing the doubtful *N. contortus* clearly establishes its oligocene age.[1]

Following the suggestions of la Harpe and of Douvillé, I have referred to *N. intermedius* the form described by d'Archiac and Haime as *N. sublævigatus* which differs from the original type of *N. intermedius* only by its large size. The comparison of countless specimens shows conclusively that, in India, all the finely reticulated nummulites belong to one species whose dimensions, like those of many other species, are extremely variable. On the one hand, we find that in some of the flysch exposures, the maximum size does not exceed 10 to 12 millimetres in diameter, practically the same therefore as with the European specimens. In Kachh, on the other hand, where the oligocene fossils of all natural groups seem liable to attain most extraordinary dimensions, (the gigantic specimens of *Breynia*

[1] *Clypeaster apertus*, a species from Kachh, described by Duncan and Sladen, was regarded by them as eocene on account of the nummulites with which it associated. (*Pal. Ind.*, ser. XIV, Vol. I, part 4, p. 11.) On referring to the type specimen, I find that the nummulites belong to the oligocene species *N. intermedius*.

carinata, for instance,) there are specimens of *N. intermedius* (*sub-lævigatus*) of as much as 30 millimetres in diameter.

The genus *Lepidocyclina*, Carter's *Orbitolites Mantelli*, makes its appearance at a very low horizon in the Lower Nari, often at the very base of the formation. It often accompanies *N. intermedius* and *N. vascus* throughout the entire thickness of the Lower Nari. In the Mula Pass, it is absent from the lowermost beds, those containing the doubtful *N. contortus;* this absence is probably not fortuitous, for the genus appears in the immediately overlying strata in which *N. vascus* replaces the supposed *N. contortus.* In the Upper Nari, the lepidocyclines are also very abundant, but are not accompanied by nummulites.

All the Nari lepidocyclines appear to belong to one species *L. dilatata* characterised by small pillars and a megasphere entirely surrounded by the second chamber. I have not succeeded in finding any forms without pillars corresponding with Lemoine and R. Douvillé's *L. Raulini*, even in the lowermost beds. In the Lower Nari, the specimens are usually somewhat stouter than in the Upper Nari, and do not exceed a diameter of 50 to 60 millimetres. They often have a central protuberance and are frequently saddle-shaped. The large specimen (Figs. 40, 41, Pl. VII, Vol. XI, ser. 2, *Ann. Mag. Nat. Hist.*, 1853) upon which Carter's description is based came from the Lower Nari, as it is stated by the author that it was associated with *N. sublævigatus.* (*Ann. Mag. Nat. Hist.*, Vol. VIII, ser. 3, p. 456, 1861.) The small transparent pillars seem to have been detected by Carter, (loc. cit. supr., Figs. 2*c*, 3, Pl. XVI,) but were interpreted as tubes of communication. In the Upper Nari, thin discoidal forms predominate, often reaching a diameter of 10 centimetres. This is *L. elephantina* M.-Ch., probably identical with the Burmese form described by Carter as *Orbitolites Mantelli* var. *Theobaldi*,[1] which, according to its discoverer Theobald, reaches a diameter of five or six inches, that is, 13 to 16 centimetres. (*Mem. Geol. Surv. Ind.*, Vol. X, p. 275.)

The Gáj lepidocyclines belong to the group of *L. marginata* with well-developed pillars and a megasphere only partly surrounded by the second cell. The largest specimens measured have a diameter of 45 millimetres. They are accompanied by Operculinæ, Rotaliæ, and other foraminifera. One lenticular and very nummulitiform species of *Operculina* is probably the form described by Carter as

[1] *Ann. Mag. Nat. Hist.*, Vol. II, ser. 6, p. 342 (1888).

Nummulites makullaensis. (*Ann. Mag. Nat. Hist.*, Vol. VIII, ser. 3, p. 375, 1861.)

According to H. Douvillé, the co-existence of reticulated nummulites and of lepidocyclines is characteristic of the Stampian.[1] The bulk of the Lower Nari would then represent the Stampian, the lowermost beds in the Mula Pass, with the doubtful *N. contortus* belonging perhaps to the Sannoisian. The Upper Nari would then correspond with the Lower and Middle Aquitanian, the Gáj with the Upper Aquitanian.

In the Mekran province, the Gáj beds consist principally of shales which pass upwards into a considerable mass of sandstones (3,000 to 4,000 feet in the Hingláj mountains), intermediate in age between the Gáj and Siwaliks. Their lower beds contain *Ostrea Verleti*[2] together with many of the typical Gáj mollusca. They may be regarded as Burdigalian and are situated at about the same horizon as the upper part of the petroliferous formation of Burma. The uppermost beds of the Hingláj sandstones which must be somewhat older than the oldest beds of the true Siwaliks,[3] and therefore of Middle Miocene age (Helvetian-Tortonian, or "Sarmatian"), contain an echinoid fauna different from that of the Gáj, and a rich series of Pectens, the most conspicuous of which has been identified by my colleague Mr. Pilgrim as *Pecten Vasseli* Fuchs, the leading form of the Kabret plateau fauna in the Isthmus of Suez, thus confirming the attribution of this fauna to the Miocene by Déperet and Fourteau. (*Comptes Rendus*, 1900, p. 403.)

Some beds crowded with small foraminifera were discovered in 1905 by my colleague Mr. Tipper in Paget Island, one of the Andaman group. They are described by Mr. Tipper as resting unconformably on Eocene beds. Amongst the specimens isolated by Mr. Tipper are the forms described by Verbeek as *Nummulites Niasi* I and II (in Verbeek and Fennema's Geology of Java and Madoura). Verbeek was

[1] Les Foraminifères dans le Tertiaire de Bornéo, *Bull. S. G. F.*, Vol. V, ser. 4, 1905. Summary and conclusions, p. 453.

[2] I am indebted to my colleague Mr. Pilgrim for this identification.

[3] It is unlikely that the Bugti beds of Balúchistán with *Mastodon angustidens* are Siwaliks; they are probably the local representatives of some horizon of the Gáj or Hingláj series. The true Siwaliks whose lower division contains the well-known fauna of Pikermi age are always unconformable to the Nari, Gáj or Hingláj.

under the impression that these two forms are zoologically related to one another, probably forming a "pair" in accordance with the dimorphism of the foraminifera. Amongst the specimens from Paget Island isolated by Mr. Tipper, are a number of equatorial sections of *N. Niasi* II which include both megaspheric and microspheric individuals. As is usual in the case of small nummulites, the two forms are very similar to one another. They are both perfectly distinct from the one named *N. Niasi* I which exhibits all the characteristic features of an *Amphistegina* and may be called *Amphistegina Niasi* Verb. The numeral II becomes then superfluous for designating the nummulite, which may be known simply as *Nummulites Niasi* Verb. So far as can be judged from published descriptions, this nummulite closely resembles the European species *N. budensis*, the main difference residing in the septal filaments which are straight in *N. Niasi*, sigmoidal in *N. budensis*.

In Java, according to Verbeek and Fennema, these foraminifera occur at a higher horizon than the large lepidocyclines. The strata with *N. Niasi* observed by Dr. Buxtorf in Borneo and in Burma are regarded by H. Douvillé as Burdigalian. (*Bull. S. G. F.*, Vol. V, ser. 4, pp. 448 and 451.)

Rocks belonging to the same system were also discovered by Mr. Tipper in Interview Island, another of the Andaman group. The rock from Interview Island is compact, so that the foraminifera cannot be isolated, but in a thin section which Mr. Tipper showed me, I recognised *Amphistegina Niasi* and *Nummulites Niasi* together with *Rotalia*, *Globigerina*, and other foraminifera, and small lepidocyclines perhaps referable to *L. Sumatrensis*.

Mr. La Touche has shown me specimens of a limestone sent by Mr. H. E. Rooke from near Kywezin, a village between Henzada and Myanoung in Burma, which contains lepidocyclines and nummulites These fossils can only be seen in transparent sections, and I have not made out to what species they belong. The rock is a compact white limestone resembling the Lower Nari of Balúchistán.

The following table shows the distribution of Indian nummulites so far as is known at present.

Table showing the Zonal Distribution of Indian Nummulites.

	Upper Ranikot.		Laki.			Khirthar.							Pegu or Mekran (*Clypeaster* beds).			
							Middle.		Upper.							
	3	4	Melting shales.	Alveolina limestone.	Ghazij beds.	Lower.	A	B	1	2	3	4	Beds without lepidocyclines.	Beds with *L. dilatata*.	Beds with *L. marginata* (Gáj).	Beds with small lepidocyclines.
Nummulites Niasi																—
„ *makullænsis*															—	
„ *vascus*														—		
„ *intermedius*													—	—		
„ *? contortus*													—			
„ *? variolarius*												—				
„ *? Brongniarti*												—				
„ *? biarritzensis*												—				
„ *complanatus*											—					
„ *perforatus*						—	—	—	—	—						
Assilina spira								—	—							
Nummulites Beaumonti								—								
„ *Murchisoni*								—								
„ *discorbina*								—								
„ *lævigatus*							—	—								
Assilina exponens						—	—	—								
„ *sufflata*					—	—	—	—								
Nummulites Douvillei							—									
„ *gizehensis*							—									
„ *irregularis*				—	—	—										
„ *atacicus*			—	—	—											
Assilina granulosa			—	—	—											
Nummulites planulatus		—														
Assilina miscella	—	—														

Illustrations of *Nummulites Douvillei* n. sp. in Plate 8.

Figs. 1 to 6. Microspheric individuals, natural size.
Fig. 7. Equatorial section of microspheric individual, enlarged.
Fig. 8. Transverse section of microspheric individual, natural size.
Fig. 8*a*. The same, enlarged.
Fig. 8*b*. Portion of surface of the same specimen, enlarged.
Figs. 9, 9*a*, 10, 10*a*, 11, 11*a*. Megaspheric individuals, natural size, and enlarged.
Figs. 12, 12*a*. Equatorial section of megaspheric individual, natural size, and enlarged.
Figs. 13, 13*a*. Transverse section of megaspheric individual, natural size, and enlarged.

NOTES ON SOME AURIFEROUS TRACTS IN SOUTHERN INDIA. BY J. MALCOLM MACLAREN, B.SC., F.G.S., *Mining Specialist, Geological Survey of India.*[1] (With Plates 9 to 15.)

THE auriferous tracts of Peninsular India are probably all comprised between the 11th and the 17th parallels of latitude and between the meridians of 74° and 78° 30′ of East Longitude. They are, so far as is at present known, restricted to a single series of rocks—the Dharwars of Foote—and are included within the Archæan Group of the Geological Survey classification. These rocks rest on the fundamental gneiss and are but the fragmentary remains of a formation that covered, in pre-Palæozoic time, not only the Peninsula of India as it exists at the present day, but also the region now lying beneath the Indian Ocean far to the south. The Dharwar rocks doubtless formed the basement of the great Gondwana land—that Permo-Triassic continent which, stretching south from India, reached at times on the one hand to Australia and on the other to South Africa. Their relations to the metamorphic rocks of those continents will, it is hoped, be described in another place, the present notes embodying merely the immediate results of rapid reconnaissance surveys during the 1904-1905 season.

Geographically the Dharwar series may be divided into four main bands and a number of smaller outlying patches, in most cases representing the bottoms of the great north-north-west and south-south-east folds into which they were crumpled in pre-Cambrian times—a crumpling so severe that it converted the granite on which they lay into a foliated rock and elongated into spindle forms the boulders of their contained conglomerates.

Three main bands were distinguished by Mr. Foote[2]—(*a*) the Dharwar-Shimoga Band; (*b*) the Dambal-Chiknayakanhalli Band; and (*c*) the Penner-Haggari Band. To these the work of the present season on the edge of the Western Ghats shows that there must be added a fourth, *viz.*, the Castle Rock Band, running through the station of that name on the frontier between Portuguese and British territories.

[1] Written May, 1905. J. M. M.
[2] Records Geol. Surv. India, Vol. XXI, p. 41.

The more important of the minor exposures are the Sandur and Copper Mt. Band: the Maski Band, in which lie the Nizam's Gold-fields: and the Kolar Band, one of the smallest in area, but hitherto in economic value by far the most important. Roughly speaking, about one half of the total area of the Dharwar rocks as at present mapped lies within the boundaries of the Mysore State, where it has been or is being examined by the Mysore Geological Department. The following notes therefore deal only with those portions lying in territory directly under British administration and with those contained within the Nizam's Dominions.

No. I.—THE GADAG BAND.

This is the northern portion of the Dambal-Chiknayakanhalli Band of Foote. It has been deemed advisable in this paper to abandon his nomenclature. The town of Dambal has so far declined in importance that its name now conveys no information, whilst Chiknayakanhalli is in the Mysore State and beyond the limits of the accompanying map. The gold-fields in this belt are becoming generally known as the Gadag Gold-fields, and the most important portion of the band lies in the Gadag Taluq. Old workings extend to within three miles of the town and railway station of Gadag, and finally no other appellation is available, the names of the main range, Kappat Guda[1] in the Dharwar District and Mallapan Guda further south across the Tungabhadra in the Bellary District, being unsuitable and little known.

Previous observers.

The earliest notice of the geology of this area is contained in papers by that officer of the Madras Army, Captain T. J. Newbold, F.R.S., who did so much sound work towards the elucidation of the problems of South Indian Geology. His conclusions, in the light of the scanty geological knowledge of his day, are always characterised by a remarkable accuracy. The various members of this band were named by him[2] with sufficient exactitude. Even the thin limestone bands in the neighbourhood of Dhoni were noted (as "sub-crystalline marbles").

A portion of the area was visited in 1852, some ten years later, by Lieutenant Aytoun, who gives an accurate and interesting sketch of the

[1] *Guda* is the Kanarese word for a range or hill.
[2] Madras Jour. of Lit. and Sci., Vol. XI, p. 42.

geology of the neighbourhood,[1] accompanied by several rough sections. The great development of cubical pyrites in the argillites attracted his attention as it had done that of Newbold.

Practically the whole of our knowledge of this belt is, however, due to the work of Mr. R. B. Foote, late of the Geological Survey of India. The first of his papers dealing with the area was published in 1874 and was concerned with the auriferous deposits of the Dambal Hills, 12 miles south of Gadag.[2]

At that time the knowledge of the various rocks which make up the Archæan complex in Southern India was extremely limited, and the Dharwar schists and the older gneisses were then not sufficiently widely mapped to admit of separation. The general features of the area were briefly sketched and the limits of the diabases and diabase-schists (termed by Foote "pseudo-diorites") were roughly mapped.

At that time also, he described, under the name of the Huttee-Kuttee Reef, the vein now being worked by the Dharwar Reefs, Ltd., and it was indeed his report on this field and the summary thereof published some thirteen years later, that finally attracted the attention to this locality that has engendered the present mining activity.

Mr. Foote's next contribution to the geology of the belt is contained in his memoir on the geological features of the South Mahratta Country,[3] in which the Dharwar outliers at Nargund and Chik Nargund, to the north of Gadag, are described.

The first map showing the general outline and direction of the band is that accompanying a later paper, "Notes on a Traverse across some Gold-fields of Mysore."[4]

Further work enabled him to materially improve on this map in one published some six years later to illustrate his two papers on "The Dharwar System, the Chief Auriferous Rock Series in South India." In the first of these papers[5] the general features of the Gadag Band are briefly summarized.

[1] Trans. Bombay Geol. Soc., Vol. XII (1854), p. 4.
[2] Records Geol. Surv. India, Vol. VII (1874), p. 133.
[3] Memoirs Geol. Surv. India, Vol. XII (1877), pp. 43, 61.
[4] Records Geol. Surv. India, Vol. XV (1882), Pt. IV, p. 191.
[5] Records Geol. Surv. India, Vol. XXI (1888), p. 40.

The most detailed description of any portion of this belt hitherto published is that contained in his last contributed paper on the subject,[1] dealing with the narrow tract within the Bellary District and reaching from the Tungabhadra river south to the Mysore boundary. The map accompanying this memoir shows that both the eastern and western boundaries of the schist band have been traced with more detail than appears to have been possible elsewhere.

The two last papers summarize all the data previously obtained.[2]

General Geology.

In the extreme north of the Dharwar District the Gadag Band is shown by Foote as emerging from beneath the southern scarp of the Kaladgi quartzites at a point about 6 miles south of Ramdrug on the Malprabha river. It is indicated on his map as a belt five miles wide; but the whole of the country being covered with cotton soil, its relations, if indeed it exists there at all, are completely obscured. As a matter of fact, the only exposures seen north of Gadag by the present writer through the whole 30 miles of the belt as marked by Foote, were at Chik-Nargund and at the striking old hill fort of Nargund.[3] (Plate 9.) The latter rises almost sheer 700 feet above the cotton soil plain and, like Chik-Nargund, is capped by Kaladgi quartzites.

The excessive width assumed by Foote arises from his inclusion in the band, as its westerly boundary, of a "contemporaneous trap flow" at Asmatti, 5 miles west-north-west of Nargund. Under the microscope, however, this rock shows as a "granulitic" olivine diabase without schistose structure and therefore is obviously younger than the Dharwars. Further, in a dry well immediately east of Asmatti village

[1] "Geol. of the Bellary District." Memoirs Geol. Surv. India, Vol. XXV (1895), p. 84.

[2] Since the above was in print a short but comprehensive paper dealing with the country in the immediate neighbourhood of Kabulayatkatti has been read by Mr. R. O. Ahlers before the Institution of Mining and Metallurgy, London. This paper contains valuable petrological notes and indicates the important relations that exist between the main Kabulayatkatti-Sangli carbonaceous band and its contained auriferous deposits. *Advance Sheets Inst., Min. and Met.*, 1905.

[3] Nargund is one of the strongest and most picturesque of the old hill forts of the Karnatak. It was fortified by Shivaji in 1674, was captured after a long siege by Tipu Sultan in 1785, and again by the British in 1858 after the murder of the Political Agent by the then ruling chief.

and of the above igneous rock, well banded hornblendic gneisses are exposed. The Asmatti rock, notwithstanding its great width, must therefore be considered a dyke intrusive in the gneisses, and no greater length or width can be claimed for this portion of the schistose band than just sufficient to include the only exposures at the Chik-Nargund and Nargund hills. Indeed the sides of a well in the north-west of Nargund town itself and about ½ mile west of the hill scarp, showed weathered rocks, unfortunately inaccessible, but decidedly gneissic in appearance.

The Dharwar rocks as represented at Chik-Nargund and at Nargund are chloritic and micaceous schists and quartzites, the latter both pure and hæmatitic, and both well banded and generally much contorted. The dip is E. N. E. from 50° to 70°. On the eastern side of Nargund the dip is 40° S. W., probably not a true dip but merely an inclination due to overburden. The schists are seamed with aplitic and pegmatitic dykes and with quartz veins, which strike and dip generally with the country, and which, ending abruptly at the base of the overlying Kaladgi quartzites, show that they are of much greater age than the latter.

The overlying quartzite is a typical Kaladgi rock, white to pinkish and quite homogeneous in the upper layers. The lowest bed is, however, a quartzite breccia in a bluish waxy quartzose matrix. The quartzite has a very slight dip at Nargund, but at Chik-Nargund dips 30°—35° to the north-east. In either case it yields sheer cliff walls throughout the whole of its thickness, the talus slopes which obscure the Dharwars reaching to its base.

The general aspect and horizontality of these beds afford striking evidence of the freedom of Southern India from extensive geotectonic disturbances during the whole of measurable geological time. Their internal structure occasionally affords further evidence to the same effect. On the southern end of the old fort, overlooking the town of Nargund, there are exposed at several horizons in the quartzites, ripple-markings still as well and as clearly defined as on that far-off day when they were first exposed by the ebbing tide of a pre-Cambrian sea.

Narrow as the schist band must be north of Nargund it would yet appear to be the most important if not the only development of the Dharwars between the main Kaladgi scarp south of Ramdrug and the town of Gadag. This patch may conveniently be termed the Nargund outlier. Diligent search southwards through the cotton soil plain, across the Benihalla stream, and along the presumed strike of the band certainly revealed some nine or ten almost microscopic rock exposures, but these were of banded gneiss, of intrusive pink granite, or of hornblendic schists, the last being of a variety characteristic of the banded gneisses.

The most northerly exposure of the Gadag Band proper may therefore be regarded as occurring a little north of Bhingadkatti, two miles west of Gadag, though the band may be mapped at least three miles further north by the plentiful shoadings of Dharwar schist scattered through the cotton soil. The Hire Handigol ridge, two miles north of the railway line, at a distance appears to be the northern prolongation of the Gadag Band, but proves on closer examination to be merely a quartzose band of obscure origin in the gneiss. It strikes N. W.—S. E. and dips S. W. crossing the nala to Chik Handigol and is probably identical in origin with a similar rock at Nulgund, 14 miles to the north-west.

Immediately south of the railway line there rises from the cotton soil plain a long low ridge, or rather pair of ridges, trending S. S. E. and denoting, as we shall find hereafter always to be the case, by their mere elevation the presence of beds of hæmatitic quartzite. These last form the crests of nearly all the ridges in the band, protecting by their own immunity from destruction the softer schists on either hand, and assuming an importance in the landscape by no means justified by their comparatively limited occurrence.

The hæmatitic quartzites near Gadag occupy an axial position in the band. They are flanked on the east by chloritic and hornblendic schists, and on the west, so far as can be seen beneath the cotton soil, by a fissile chlorite schist. East of Bheldadi the two main hæmatitic quartzite bands, with indeed the whole country, swing to the east, rising to a height of 800 feet above the level of the adjacent cotton soil plain, and stretching to the hills overlooking Dambal. A third more westerly banded hæmatite quartzite runs through Nagavi village S. S. E. and then S. E. to the village of Dhoni, and, occurring at a lower horizon, has escaped the erosion that, north of Dhoni, has given the two superior bands strikes and dips at first sight apparently so erratic. The most westerly hæmatite quartzite belt mapped is that which lies immediately east of the mines at Kabulayatkatti.

It is at this point that the band attains its maximum breadth of fifteen miles. A generalized section from east to west—from Dambal through Kabulayatkatti (more generally known as Kabligatti) to near Mulgund—shows the following order of succession :—

1. Hornblende schists.
2. Chloritic schists with calcareous and ferruginous bands.
3. Argillites.
4. Felsites and diabase schists with occasional narrow bands of chloritic and micaceous schists.

The relations *inter se* of these rocks are far from clear. The hornblende schists which form the eastern portion of the belt are massive and show in the field little evidence of foliation. The succeeding chlorite schists dip to the W. S. W. at angles increasing from 35° to 50° as the central Kabulayatkatti ridge is approached. These beds of green chloritic schist are somewhat important as containing bands of a greenish grey to bluish limestone, in places 30 feet in width, and striking with the country N. N. W. and S. S. E. and dipping W. at 45°. Immediately overlying the limestone at one exposure, 3 miles W. S. W. of Doni, is a crushed breccia of fragments of quartz, talcose schist, and limestone cemented by a calcareous cement. The limestone bands are to be regarded as secretions of and replacements by calcareous matter along fissure planes rather than as true sedimentary deposits. Their calcareous matter is derived mainly from the decomposition of a soda-lime felspar. Other carbonates, as breunerite and chalybite, occasionally occur.

In the neighbourhood of Dindur the green chloritic schists give place to black pyritous argillites weathering red to reddish-buff on exposed surfaces. The pyrites occur in large isolated crystals often replaced when near the surface by pseudomorphs of limonite. They may, as will hereafter be shown, be considered to owe their deposition to the carbonaceous nature of the argillites. The argillites, with the associated chloritic schist bands, have, in the neighbourhood of the Kabulayatkatti gold mines, an apparently synclinal disposition showing a broad eastern and a narrow western side. The synclinal axis, as will be seen from the accompanying small sketch map (Plate 12), would lie about 600 yards east of the surface workings of the Dharwar Reefs Company. From the presence, however, of a diabase schist along the axis, and from the sudden steepening of the dip on the western side from 50° to 80° as the diabase is approached, it is considered probable that there is no true synclinal fold but that the change in dip is due to a fault fissure into which the ancient magma now forming the diabase schist has been intruded.

To the west of the argillites, from Kabulayatkatti to beyond Hosur, there lies a complex, seven miles broad, of felsite, diabase schist, massive schist, micaceous schist and fissile chloritic schist. Their relations are greatly masked by the soil with which they are covered, but on present evidence the second, if not also the first, must be considered as being originally intrusive into and therefore younger than the massive and chloritic schists. The quartz porphyry which stretches north as a narrow band from the Kabulayatkatti village to Bheldadi is to be considered as a varietal form of the prevailing felsite.

South of the Dambal-Hosur section line the great Kappat Guda by reason of its included beds of banded hæmatitic quartzite, rises to a flat laterite-capped peak a little more than 3,000 feet in height. This laterite and that capping the Mallapan Guda, 3,172 feet, are the only two exposures of high level laterite along the course of the Gadag Band. Viewed southward from the summit of the former peak the rocks in the immediate foreground are so intersected by deep valleys that their structure is not at once apparent. To the east, and almost immediately underfoot, a sheer precipice marks a fault which has, in all probability, raised the beds on its western side, giving them at the same time their local westerly dip, since further south the dip of the whole breadth of the band is east and is that of the portion here lying to the east of the fault. In the middle distance, however, and further south towards the Tungabhadra the landscape clearly reveals the underlying geological story. A series of parallel ridges with precipitous western escarpments and long gentle slopes to the east indicate, on the eastern side of the band, fissile chlorite schists with stiffening bands of hæmatite quartzite. A broad flat valley immediately west of the chlorite schists shows the change to a gritty felspathic schist. The western boundary of the valley is formed by a belt of low, irregular, rugged hills suggesting, in the distance, a granite range, but proving on closer examination to result from the weathering of a broad conglomerate, or rather boulder, bed that stretches from Sortur southward across the Tungabhadra river and ends six or seven miles further south in the Bellary district. West of the boulder bed runs another typical series of ridges of chlorite schists with hæmatite quartzite ribs, the whole being underlain by a second boulder bed, without however the persistence or size of pebble of the first. Finally the western portion of the belt is low-lying country formed by mica schists and by diabase schists, the last resting on the granite.

The best cross section obtainable along the Gadag Band is probably that afforded by the Tungabhadra river as it breaks across the belt. The rocks from east to west—from Shingtalur to Bidarhali—are:

16. Fissile chloritic schists weathering to micaceous schists.
15. Banded hæmatitic quartzites (at the temples).
14. Massive chloritic schist.
13. Thin boulder bed with much flattened pebbles.
12. Banded hæmatitic quartzite.
11. Massive chloritic schist.
10. Felsite.
9. Diabase and hornblende schist.
8. Massive gritty felspathic schist.
7. Fissile chloritic schist with banded hæmatite quartzite. (Hamigi.)
6. Boulder bed with diabase dyke.
5. Fissile chloritic schist.
4. Boulder bed.
3. Micaceous schist with banded hæmatite schist.
2. Diabase dyke.
1. Massive hornblende schists.

This section is seven miles long, and the dip of all these beds, or rather of their foliation planes, is E. N. E. at 40°—50°, but it cannot therefore be assumed that the Dharwar beds have the thickness of five miles thus indicated. While it is clear from the axial disposition of the main boulder bed, to be taken as the test stratum in this case, that the folding stress has been exerted at right angles to the strike, it is equally clear that this very direction would offer the least resistance to the overfolding, and more particularly to the overthrusting, which must from the extreme character of the metamorphism be assumed to have taken place. Close examination of the section itself yields no decided evidence for or against the repetition of beds. Mr. Foote gave this section a width of only five miles, but the western hornblende schists from west of Gumgol to Bidarhalli can certainly not be dissociated from the Dharwar rocks.

South of the Tungabhadra river (Plate 14) there is a break of some two miles in the band, the rocks sinking down to the level of the river.

Mr. Foote[1] has assumed the existence of a great east and west fault to account for the sudden disappearance south of the river of the banded hæmatite quartzites on the east, and for the plain on the south bank. Closer examination of the rocks shows, however, that the quartzites do not disappear, but merely lose their ferruginous cement and therefore their power of resisting denudation and of protecting the associated chloritic schists. It is, moreover, difficult to understand how the transverse east and west fault postulated could throw down the eastern hæmatite quartzites without throwing down and disturbing to an equal extent the parallel beds at Hamigi only 2½ miles to the west. From a comparison of the accompanying maps it will, however, be seen that the Hamigi quartzite bands are clearly continuous across the Tungabhadra, as are indeed all the members of the series. The plain on the southern bank, which doubtless strengthened the idea of extensive faulting, is no more than the swathe cut by the river in its course.

Two miles south of Hamigi the banded quartzites that run through that village rise from the plain to form a low ridge four miles long reaching to Shivapuram. A mile south-east of its termination a similar ridge, three miles long, is formed by an eastern parallel axial band of hæmatite quartzites. These are the only two elevations of any importance for eight miles south of the river. The country is here composed mainly of fissile chloritic schists together with the rapidly thinning ends of the various beds that cross the Tungabhadra, all alike dipping E. N. E. at from 45°—60°.

South and east of Nagati Basapuram the character of the rocks changes. Running through that village and forming the great rocky north-eastern spur of Mallapan Guda, is a broad band of fine quartz-pebble conglomerate, greatly compressed. Proceeding south along the ridge, the pebbles become larger, and at the southern bluff are a number of old workings to which reference is made in another place. Half a mile north of the Mallapan Guda the pebbly conglomerate, which strikes N. W.—S. E., is thrown down by an east and west fault and is covered by a broad banded hæmatite quartzite, but reappears a couple of miles to the south from beneath the escarpment. Allied to this conglomerate is a parallel band forming a hill outlier just south of Devagondanahalli and continued through the Dharwar projection which runs out into the granite towards Mudenuru.

[1] Memoirs Geol. Surv. India, Vol. XXV, p. 85.

The Mallapan Guda, 3,172 feet, is the highest point in the Gadag Band. Here as elsewhere in the Dharwar rocks height is merely an expression of the number or size of the hæmatite quartzite bands, and there are at least five parallel bands in the main peak, the most westerly being the broadest yet seen. The range as it trends away to the south towards the gap at Kanavihalli shows the characteristic western escarpment and the long eastern slope.

To the east of the Mallapan Guda there lies a complex of hornblende and diabasic schists, the former weathering to low irregular rounded hillocks. These rocks again occur further south along the eastern side of the belt, *viz.*, E. of Bhavihalli and S. E. of Nagarakonda, and are probably portions of a once continuous band.

South of the Kanavihalli gap rises the Jajkul Guda, four to five miles long, and the only representative, in the Bellary portion of the belt, of the red to yellowish-buff auriferous argillites of Kabulayatkatti. On the east, overlooking the village of Konganahosuru is a narrow band of the Nagati Basapuram pebbly conglomerate. The western portion of the main belt is brought into prominence near Dadigaranhalli by a number of parallel hæmatite quartzite bands.

At Nichchapuram the hæmatite quartzites disappear and the whole band of fissile chloritic schist sinks at once to the level of the plain, rising from it to form a series of isolated ridges only after the Mysore boundary line, seven miles further south, is passed. The most easterly ridge of these hills, however, lies along a portion of the Mysore boundary line and shows a central band of gritty conglomerate with fine pebbles, the associated rock being a silvery fissile schist with an easterly dip. The rocks forming the eastern boundary of the belt south of Nagarakonda are, as has already been stated, a dark massive hornblendic schist.

Among the most striking geological features of the belt are the numerous doleritic and diabasic dykes that ramify everywhere throughout the rocks. They have no general orientation, but are, on the whole, rather meridional than otherwise, owing probably to ease of injection along the foliation planes of the schists. They are readily recognised, even at a great distance, by their vegetation, which being supported by a soil richer in alkalis than that of the schists is always more luxuriant and, at certain periods of the year, greener than that of the adjacent rocks. They further furnish an interesting example of the fact that it is not always the harder rocks that withstand best the weathering agents of nature, for in this area transverse gorges in the hills are found to be almost invariably due to erosion along the courses of cross dykes. Where they have been preserved along the crests of the ridges, as north of Kabulayatkatti, they owe their preservation solely to the induration by their heat of the adjacent rock which, as in the above instance, stands up a rocky wall on either side of the smooth sward produced by the weathering of the dyke. In no instance was a dyke observed to stand above the level of the adjacent rocks. The dyke rock furnishes the best building stone in the neighbourhood and is largely worked by wandering tribes of Vaddars or Waddars, who with the aid of a small fire laid along grooves split the rock with great accuracy into rudely cubical or prismatic shapes.

The relations of the Dharwars in this belt with the adjacent gneisses are not very evident, and as a result of the present reconnaissance, only so much is clear, *viz.*, that the gneisses are to be regarded as the fundamental rocks on which the Dharwars were laid down. In this connection a much weathered section on the southern side of the Dambal Tank is instructive. It shows a gradual passage from gneiss to hornblende schists by way of white sands and clays of gradually increasing depth of colour. The white sands probably represent a quartz schist derived from an original arkose. All—gneiss, quartz schists, and dark schists—are now apparently conformable as a result of the stress to which they have been subjected.

During the course of the present examination, no confirmation of Mr. Foote's assumption[1] that the eastern boundary of the belt is a fault line was obtained. Indeed the above described section at Dambal and another at Shingtalur on the Tungabhadra, where the pressure has been so great that the gneiss has been forced as tongues 2—3 inches thick for five or six feet into the schist along its cleavage planes, proves the contrary. In all cases where the junction of gneiss and schist could be seen there was a total absence of brecciation. To faulting, however, is probably due the preservation of the schist peninsulas which in the Bellary District run out into the gneiss on the eastern side of the belt.

It must clearly be understood that the various formations delineated on the accompanying map can have, owing to various reasons, only a rough approximation to their true outlines. Much of the area, and especially is this the case on the western side of the band, is covered with cotton soil, and it is only at wide intervals that an outcrop is

[1] Memoirs Geol. Surv. India, ol. XXVI, p. 4.

available. Again, some of the formations are undoubtedly successive in age, and when all are not only metamorphosed but also obscured, it becomes difficult to say where the line of demarcation should be drawn. The map must in these parts be regarded therefore as a general expression of the underlying rocks rather than as giving a detailed and accurate outline of their areas.

Perhaps no other Dharwar area in the Indian Peninsula shows such a diversity of strata as does the northern portion of the Gadag Band. A close study of its geology should therefore throw abundant light on the origin of less well preserved Dharwar patches and would also incidentally furnish an interesting field for the study of the various problems of regional dynamic metamorphism.

Petrology.

The rocks of the belt may be conveniently divided, according to their probable origin, into two main groups, sedimentary and igneous though the affinities of some of the schists here grouped with the sedimentary rocks, are, to say the least, extremely obscure.

Sedimentary: *Boulder beds or conglomerates.*—These reach their greatest development north of the Tungabhadra as long narrow beds stretching more or less parallel with the boundaries of the band and dipping, as indicated by the foliation of the matrix, almost vertically. They are not true conglomerates, inasmuch as they do not consist wholly of boulders, but of boulders embedded in a schistose felspathic matrix stained with chloritic matter. On the edges of the boulder beds the boulders become less numerous and the beds gradually shade away to an extremely fissile felspathic schist, thin beds of which also occur throughout the main boulder beds. The matrix in the thicker boulder beds is occasionally quartzose. The pebbles contained are granite, aplite, quartz porphyry, felsite, true quartzite, and banded jasperoid quartz. They range up to 16 inches in length. The majority have adjusted themselves to the positions required by the crumpling pressure by the development of numerous shearing planes, all parallel with the direction of the stress (which appears to have been at right angles to the strike of the beds) so that each successive portion of a boulder projects a little beyond, or recedes a little from, its neighbour according to the direction in which it is viewed.

The absence of hornblendic and of diabasic schist boulders in the conglomerate is perhaps noteworthy as indicating for these a later origin, though it must not be forgotten that such rocks do not weather readily into boulder form. The absence of gneiss indicates that the fundamental rocks had not, at the time of the deposition of the boulder beds, had impressed on them the gneissic character. But the time devoted to the examination of these rocks was much too short to permit of any such generalizations with safety. An extended examination of these boulder beds may confidently be expected to furnish the key to problems now obscure or insoluble.

Pebbly Conglomerates.—These have so far been found only south of the Tungabhadra. They have been noted to the S. E. of Devagondanahalli; at Nagati Basapuram; and to the S. E. of that village rising up to the Mallapan Guda; 2½ miles east of Khananahalli; and on the eastern slope of the Jajkul Guda, 1½ miles S. W. of Konganahosuru. They are composed of small quartz pebbles cemented by a quartzose matrix and occasionally pass by imperceptible gradations into a quartz grit, such as that occurring on the Mysore boundary, west of Tulahalli.

Massive Gritty Schist.—This rock is best developed in the long valley running north-west from the Tungabhadra through Murdi and Chik-Vadvati to Kadkol. It is a dark grey massive rock, weathering cuboidally and showing in hand specimens no sign of schistosity. Under the microscope it shows as an aggregate of oriented quartz and felspar grains with a little chlorite disposed in bands through the rock. On the whole therefore this form must be regarded as an original greywacke or felspathic grit.

Argillite.—Two main areas of this rock have been distinguished. The northern, in which the Dharwar Reefs and Sangli Gold Mines are located, stretches from Nabapur for eight miles south to the hills overlooking Kadkol and has an average width of about two miles. The southern exposure forms the Jajkul Guda in the Bellary District and has about one-fourth of the area of the above. In both cases they shade imperceptibly into fissile chlorite schists from which they may be distinguished only by their greater massiveness, by the characteristic red hills they yield on weathering, and by the abundant presence of pseudomorphs of limonite after iron pyrites. Though red on the surface the deep workings of the Dharwar Gold Mines show the rock to be black and carbonaceous in depth. It is to the well-known reducing power of carbonaceous matter on ferrous salts that the pyrites crystals owe their origin. There can be little doubt that these argillites represent original carbonaceous shales, and it is in the most highly carbonaceous band that the Kabulayatkatti-Sangli series of reefs is contained.

An excessively fissile form of this rock occurs on the Mysore State boundary east of Tulihalli. It is a silvery rock with almost metallic lustre. Under the microscope it shows as fine felspathic matter much stained with iron oxide. Its silvery lustre is due to fine fragments of an undetermined clear doubly refracting mineral showing no polarization colours.

Chlorite Schists.—These are, in the main, fissile rocks, and occupy by far the largest portion of the band. They are grey to greenish grey, and are occasionally spotted with magnetite (as two miles east of Sangli). Under the microscope they are well banded generally showing rounded or elongated crystals of quartz and felspar in an irresolvable matrix, and with ferruginous material and ferro-magnesian silicate occasionally wrapping round the "eyes" of quartz or felspar. Until direct proof to the contrary can be adduced the chlorite schists, and therefore the greater portion of the Gadag Band, may reasonably be considered to be of sedimentary origin and to have been derived from original successive muds, shales, and slates. In these schists the foliation is often accentuated by weathering. Massive beds without any indication in hand specimens of schistose structure were found, when weathered, to yield a most fissile rock, a change which, until its nature was clearly recognised, was productive of some confusion.

Hæmatite-Magnetite Quartzites.—These, though relatively of little importance, are yet responsible, as has already been mentioned, for the characteristic features of the Dharwarian landscapes. The quartzites are always well-banded and are often longitudinally crumpled and folded into vandykes to a remarkable extent. The bands are often very thin but are always distinct. The component minerals are quartz, hæmatite and magnetite, any one of the two first prevailing at times to the exclusion of the other two.

The origin of these banded and contorted hæmatite-magnetite cherts is by no means clear, but the simplest explanation of their origin is that they represent original highly ferruginous shales, which owing to the rearrangement of the minerals and the natural segregative tendency of silica and of the iron oxides, formed, before they were depressed below the reach of oxidising waters, normal ferruginous cherts containing simply limonite and cherty matter more or less banded. Passing from the upper zone of weathering and being subjected to the stress of orogenic movements, the bands were contorted and active dehydration took place, converting the limonite into hæmatite. Where pure iron carbonates occurred with the limonite, the descent to the region of sulphide waters produced magnetite. Hence we have all the constituents of the rock. Their highly banded structure is a necessary concomitant of the modification of the segregative forces by orogenic movements. Where, however, the descending iron carbonates were not pure, and containing lime and magnesia, came under the influence of siliceous waters, grünerite or actinolite were formed. This is probably the origin to be ascribed to some of the already mentioned actinolitic bands. The foregoing explanation with the necessary modifications is also competent to account for the existence of similar hæmatite-magnetite-quartz rocks in igneous schists, as those of the auriferous series of Western Australia.

Limestones and Calcareous Bands.—Calcareous rocks are developed mainly among the fissile chlorite schists, though at the break in the ridge north-east of Shivapuram, five miles south of the Tungabhadra, they are interbedded with banded hæmatite quartzite. The most extensive beds are those to the W. S. W. and to the W. N. W. of Doni. The more calcareous bands, not entitled to the term limestone, are characterised by the presence of *kankar* along their outcrops When broken up they often disclose an association with chalybite and with breunerite. In all cases the calcareous bands are to be regarded as infiltrations from the decomposed and decomposing country rock.

Talc Schists.—These rocks occur only in a few places and mainly in the neighbourhood of Suganhalli, north of the Balhati-Mundargi road. In one place only, in the little hillock 1½ miles N. E. of Hamigi, on the Tungabhadra river, do they appear to have been worked for potstones. Under the microscope they show a platy aggregate of talc scales with occasional grains of quartz. The greasy schist met with along the foot wall of the Hosur reef is from its hardness chloritoid or pinitoid rather than talcose.

Mica Schists.—Of doubtful origin are the extremely fissile biotite mica schists which cross the Tungabhadra river west of Hamigi and extend for some distance north beneath the cotton soil. They decompose with such ease that it is very difficult to obtain a fragment that will not crumble in the hand, but a specimen from Tarikop, sufficiently hard to be sectioned, showed a fairly clear mosaic of quartz and felspar spotted throughout with brown biotite mica. A similar rock, too small in area to be marked on the accompanying map, runs through the Hosur workings to Harti Hill.

Igneous: *Hornblende Schists.*—These rocks occur in three main areas on the east of the belt; (*a*) north of Dambal, (*b*) in the neighbourhood of Adavimallanakeri, and (*c*) south of Nagarakonda, east of the Mysore State boundary, the two last localities being in the Bellary District. They are also developed in the west of the band at Bidarhalli on the Tungabhadra river. They are all hard, black, compact rocks with little indication in hand specimens of schistosity. Two samples obtained are almost actinolitic. These are from the Gadag-Dambal road four miles north of Dambal and from a hillock north of Suganhalli. The first shows much untwinned albite felspar with long green crystals of hornblende. Epidote is common and it is evident that the original components of the rock have been thoroughly reconstituted. The second section also shows the long bladed actinolitic form of hornblende, but the rock is here somewhat weathered and the dark ferro-magnesian silicate stands out in bold relief from the light grey matrix.

The great hornblendic schist bed which underlies the banded hæmatite quartzites in the main escarpment overlooking the villages of Bheldadi and Nabapur and which sweeps with the overlying rocks S. E. towards Dambal shows fairly conclusively under the microscope that it was originally a basic igneous rock, and is perhaps to be regarded as intrusive in its present position. The felspars with their large extinction angle indicate a labradorite type. The hornblendes, both brown and green, are scattered in needles throughout the mass and are the relics of originally large crystals that have been fractured by tension and their component parts separated by the formation of secondary felspathic matter along the cleavage cracks.

Three sections from the intermediate hornblendic area, *viz.*, (*a*) W. of Verakanhalli, (*b*) S. W. of Hugaluru, (*c*) E. of Govindapuram, are interesting as showing the changes which take place with approach to a younger granitic mass and with consequent reconstitution of the component minerals. The first shows the large porphyritic hornblende crystals fraying out and breaking up. They are first bent, the arcs of some indeed subtending an angle of 120°, and are then broken, small fragments being separated from the main mass by the development of interstitial matter along cleavage and fracture planes. In some cases fragments with differing orientation are obviously squeezed together. The second section, a further development of the foregoing, shows a confused aggregate of minute hornblendes with some chlorite and with very little clear interstitial matter. The third, close to the granite, shows a thoroughly reconstituted rock. The cloudiness of the intermediate type has disappeared and both felspars and hornblendes are large, clear and even-grained, the latter showing a tendency here and there to even assume idiomorphic forms. These hornblende schists are the representatives in the Gadag Band of the auriferous hornblende schists of the Kolar and Hutti Gold-fields.

Diabase Schists.—These are light grey to greenish grey rocks with a pale green porphyritic constituent when viewed microscopically. Under the microscope the rock, though much weathered, preserves its holocrystalline outlines. The felspars are so much decomposed as to present no sign of twinning, some sections being completely saussuritized. The other important mineral is a faintly pleochroic uralite, showing in places the characteristic hornblende cleavage. The ophitic structure is distinct in one specimen only (that from ½ mile east of Kabulayatkatti), in others it is not evident. Epidote, zoisite, apatite, and leucoxene are present, the two first resulting from the saussuritization of the soda-lime felspar. The rock as a whole is well on the way towards a hornblende schist. It is the "pseudo-diorite" of Foote's earlier papers, and is perhaps best developed between Sortur and Sangli.

Quartz Porphyry.—This rock was found only as a narrow band forming a ridge running from the Kabulayatkatti village north to near Bheldadi village. It is a greyish brown rock, with blebs of quartz showing distinctly in hand specimens. Under the miscroscope quartzes are seen to be numerous, clear, rounded, and corroded. They are occasionally fissured, in which case the fissures are filled with the ground mass. Large crystals of microcline with characteristic pectinate structure occur. The ground mass is a cryptocrystalline aggregate of quartz and felspar.

Felsite.—This rock is widely developed to the west of the Dharwar Reefs Mine. The quartz porphyry above described is probably to be considered as merely a varietal form. The felsite is dark grey and extremely compact, breaking with a sub-conchoidal fracture. Under the microscope the original ground mass is irresolvable and much has been converted into epidote and calcite. In one section a large crystal shows the outline of an orthoclase felspar, but the felspathic matter has been completely replaced by epidote.

From the field evidence and from that afforded by the microscope, it is far from certain that these rocks are of igneous origin and that they are not highly altered sedimentaries, but in default of direct evidence the simplest explanation of their origin is offered, and they have consequently been grouped with the former.

Pseudo-sphærulitic rock.—Probably to be associated with the foregoing is the massive rock from the high bluff above Kadampur village on the road from Dambal to Gadag. It is composed, as seen in thin sections, almost entirely of pseudo-sphærulites, resulting from an extreme development of a micrographic intergrowth of quartz and felspar. The section contains abundant magnetite dust, but all disposed in thick rings round the pseudo-sphærulites.

Intrusive Dykes.—These are numerous and ramify in all directions through the schists and out into the gneisses. They cut through all the members of the series and, as evidenced by the complete absence of all schistose structure, are subsequent in age to the general folding of the Dharwars. They are not known to be intrusive through the Kaladgi quartzites and must therefore be termed pre-Cambrian and relegated to the period between the final crumpling of the Dharwars and the deposition of the Kaladgi series. Some idea, however, of the vast interval in geological time that must have elapsed between the deposition of the Dharwars and of the presumably pre-Cambrian Kaladgi quartzites is gained by the consideration of the fact that it was sufficiently long to allow for the uptilting and for the subsequent complete metamorphism of the various members of the Dharwar series into their present aspect. That regional metamorphism ceased before the deposition of the Kaladgi quartzites is clear from the fact that these are still horizontal and still retain, as in the case of the ripple markings already mentioned, features impressed on them at the time of their deposition. All therefore that can be surmised about the age of the intrusive dykes is that it is much nearer that of the overlying Kaladgis than that of the containing Dharwars.

Two series of dykes have been distinguished, *viz.*, a doleritic and a diabasic. No evidence was obtained throwing light on their relative ages, though a most careful examination was made of the only spot, one mile E. S. E. of Attikatti, showing the intersection of the two series. They are, however, so similar in composition that they are probably contemporaneous. Generally speaking, the diabasic dykes occur south of Attikatti and the doleritic dykes to the north of the same village.

The best representative of the doleritic series is the great dyke 120 feet wide which, commencing at Nagavi, runs south through the Kabulayatkatti village to the bluff overlooking Attikatti where it turns to the east towards Doni. It has thus a course, actually traced on the surface, of nine miles. From its course across the Kabulayatkatti and

Nabapur nalas where in either case it bends to the west on descending from the higher ground it has probably a decided dip to the west, or away from the mine workings at the former place. On the bluff to the north of the mine the dyke is intersected and faulted by a younger dyke of the same doleritic type.

In thin section the rock is holocrystalline showing clear twinned and untwinned felspars, the former giving extinction angles of 35° and therefore approaching labradorite. The pyroxene is colourless or greenish with characteristic cleavage. Olivine occurs in a single instance, but is nearly completely altered to serpentine. Ilmenite altering to leucoxene is present, as also is apatite.

The diabasic series, which includes the Sangli dykes and all to the south of Sangli, does not differ markedly from the above, except in the complete absence of olivine and in the ophitic disposition of the augite, a structure not always well marked. In hand specimens, however, the difference is at once apparent, the dolerite being always a black close-grained compact rock, while the phenocrysts in the diabase are occasionally very large, and the rock as a whole is markedly light in colour by reason of the porphyritic white felspars.

A noteworthy variation from the type occurs in a pseudo-amygdaloidal diabase dyke lying about a mile S. W. of the Attikatti village and a quarter of a mile east of the Kabulayatkatti-Sangli road. It appears in hand specimens and also at first sight under the microscope to be a truly amygdaloidal rock containing numerous rounded apparently vesicular cavities as well as solid replacement spheres. In thin sections the spheres are seen to contain much darkly stained chloritic matter penetrated by black acicular needles of a non-transparent body. The numerous felspar needles in the rock matrix in the immediate vicinity of the pseudo-amygdules are, however, set with their long axes parallel to the circumference of the dark circles and immediately suggest fluxion grouping round a solid body. It is therefore considered probable that the cavities and spheres merely represent original rounded olivine crystals, which have by chemical interaction or by surface decomposition been completely removed. Indeed the explanation is at once suggested by a comparison with the rock to be immediately described.

A good example of an olivine diabase is furnished by the extensive dyke at Asmatti, N. W. of Nargund (the "Asmatti trap flow" of Foote). This is essentially an olivine-felspar-augite rock, the augite, though occurring in relatively small quantity, often wrapping round both the rounded and corroded grains of olivine and the long lath-shaped triclinic felspars.

Economic Geology.

Gold is the only mineral of present economic importance in the Gadag Band. Its existence there has long been known owing to the washings made year after year for a short time after the annual rains. For simplicity of description the occurrence of the metal may be separated into two divisions—alluvial and reef gold.

Alluvial Gold.—Though the washings for alluvial gold have certainly been carried on in this area for ages, they never seem to have been more important than they are at the present day. For while the auriferous area lies not far from the old road from Goa to the great Hindu capital of the south, Vijayanagar, there is yet no mention of any gold washings by any of the European writers of the fifteenth and sixteenth centuries—Nicoli Conti, Federici, Varthema (Italians), Nikitin (Russian), Nunez, Barbosa, Paes, etc. (Portuguese)—or in the chronicles of Ferishta or of Abdur-Razzak.

The Desais or chiefs of Dambal formerly levied a tax on the gold washers, but these appear to have pursued their calling free of taxation after the death in 1800 of the last Desai, who was hanged, apparently as the result of a misapprehension, over the gate of his own fort by the Duke of Wellington.

In 1839 the Collector of Dharwar forwarded to Government about 15 grains of gold and gold dust obtained from the Kappat Guda, which proved, on assay, to be 927·5 fine, the remainder being silver. Captain Newbold (1842—1845) found the banks of the gold-yielding streams (those of Doni, Sortur, Harti, and Jilgiri) crowded with jalgars or gold-washers, and estimated the yield from these streams, after an average monsoon, at about 200 ounces per annum.[1] The Kappat Guda gold tract was brought to the notice of Captain Newbold by one Trimulrow, a Brahmin who had gained some mineralogical knowledge in Bombay. The latter saw only the washed gold dust, but Captain Newbold witnessed the operations of washing and was of opinion that it was most carelessly done.

[1] Madras Jour. of Lit. and Sci., Vol. XI, p. 42.

Lieutenant Aytoun in 1852, when investigating the mineral resources of the Bombay Karnatak, found that owing to the more liberal assessment introduced by the Land Revenue Survey, many of the gold-washers had taken to the cultivation of the soil as a more certain means of gaining a livelihood.[1]

Four years later Mr. G. W. Elliot, Assistant Collector of Belgaum, made a special investigation of the field and reported eventually that the gold occurred in a quantity too small to repay the expenses of working.

In 1861 an Australian digger named Le Souef prospected the country on behalf of Government, and a year later formed a joint-stock company to work certain areas near Sortur. Work was carried on for some three years until Le Souef disappeared suddenly in 1866. According to Mr. Foote he had spent £15,000 of the company's money and had obtained no return other than a few nuggets of Australian gold which he sent from time to time to Bombay to allay the anxiety of the shareholders.[2]

The great numbers of jalgars mentioned by Captain Newbold in 1842, had declined to three only when Mr. Foote visited the field some thirty years later. These were employed in washing in the various streams and it was found that the most productive were the Sortur, Doni, and Jilgiri streams in the order given. The gravel and material used by the jalgars was collected in small quantities from different points, favourite spots being the gravel banks at the bend of a stream, the alluvial gravels below high flood level, and kankar deposits covering schists within reach of flood waters. Four men washing with two troughs returned to Mr. Foote 6½ grains of gold from 1½ cubic yards of material washed. The gold was valued at 1*s.* 2*d.* or at the rate of £3-17-6 per ounce. Since, so far as the present writer could ascertain, the use of long troughs in the process of washing has been abandoned, Mr. Foote's description of the process may be quoted in part.

"The wash-dirt is scooped up with a stout broad short-handled hoe, and carried in a basket or large wooden tray to the washing box which has been fixed at the water's edge and propped with stones to the required slope. The washer sits on a large stone in the water close to the side of the box, which is an oblong construction made of light planks and open at one end. It is three to three and a half feet long, twenty inches wide, and nine inches deep, and strengthened with

[1] Trans. Bomb. Geol. Soc., Vol. XI, p. 1.

[2] Records Geol. Surv. India, Vol. VII, p. 135.

clamps. A stick of elastic wood is jammed against the sides and bottom at the lower and open end to form a catch. When this is done the washer begins to ladle water on the wash-dirt kneading it with his left hand and throwing out all the larger pebbles. The ladle or rather scoop used by the jalgars was made of a gourd of the calabash tree, *Crescentia cujete*, with one end cut off.........The washing and kneading went on till a layer of sand formed in the box, so thick that the stick at the lower end was no longer a sufficient catch and a second stick was jammed in and the washing process begun again until the layer of sand had risen almost level with the second stick. Both sticks were then removed, the washer stirred the layer of sand with a short stout piece of wood, and then swept everything into the large wooden tray, held below the open end by the assistant. The washer then took the tray, placed it in the water, and shook and washed it till nothing remained at the bottom but fine sand, most of it black. He then slightly tilted the tray, and, by judiciously dropping water out of his hand on the small layer of sand, drove the lighter particles forward and left the spangles of gold exposed. This small residue was carefully gathered by washing it into a half cocoanut shell, and was taken home to be treated with mercury."

Mr. Foote was convinced that from the apparently careless handling there was considerable waste in the process of washing, but, owing to the extremely high specific gravity of gold very great liberties may be taken with the sands, quite sufficient indeed to deceive the casual observer.

It will be noted as an interesting fact that the process above outlined is precisely that described elsewhere as followed in regions as far apart as the Jashpur State in the Tributary Mehals,[1] and the rivers of Assam [2] and in those cases there is certainly very little waste.

The gold was refined by beating out into plates and repeatedly exposing the thin sheets to a heat below the fusion point of gold in a mixture of salt, borax, and the ashes of cowdung or powdered brick. The function of the two last was purely mechanical and served to keep the sheets apart. The salt united with the copper and silver to form fusible chlorides which were carried off in the slag. Where simple fusion was required borax alone was used.

At the present time there are 15 washers in the district, 9 at

[1] Records Geol. Surv. India, Vol. XXXI, p. 66.

[2] Loc. cit., p. 213.

Kanavi, 3 at Harti, and 3 at Sortur. They wash only during the rains, sometimes getting nothing for a day's work and very rarely obtaining more than three annas a day. The gold is extremely fine, and all agree in stating that coarse gold is not found. The only apparatus now used in washing is a shallow wooden tray, not unlike an Australian prospecting pan. It is about 2½ inches deep with an upper diameter of 16—18 inches, and a lower of 12 inches. The older trays are fitted at the sides with wooden projections or handles. The only evidence of washing seen during the present season was in the vicinity of Nabapur and along the nala towards Doni, where the stream gravels had been disturbed.

Mr. Scholt writing in 1874 states[1] that 12 days' washing at Sortur yielded him gold worth about four to six shillings. He was of opinion that the alluvial deposits would never pay to work since they were confined to a few small streams and blind watercourses whose bed rock was almost bare, showing a very scanty supply of wash-dirt. With this opinion, and for the foregoing reason, the present writer completely concurs.

During the course of the examination of the band an opportunity was found of washing for gold in the Tungabhadra river at its passage across the Dharwars. Though physical conditions for concentration are here very favourable, the upturned edges of the transverse beds forming admirable ripples, no prospects showed more than a grain of gold to the ton and few one-fourth as much.

A second area in which washing is carried on lies in the Bellary District south of the Tungabhadra. A vague hint of the occurrence of gold in that area is afforded by Dr. Balfour who states[2] that there was a vague report to the effect that gold was found in streams near Camvehully, and at a hill bearing the name Jageracully Guda. The information was correct, the places mentioned being Kanavihalli and the Jajkul Guda. These were visited by Mr. Foote[3] and described in his Manual of Geology of the Bellary District. The best streams are those which flow east and south from the Jajkul Guda, in order of richness being the Konganahosuru; the Chiggateru, at Changalu in the valley west of the Jajkul Guda; and the Maiduru stream. Mr. Foote reports having obtained large grains from the Konganahosuru stream, but an exhaustive trial of the likely spots in this stream made by the writer during the present season rarely gave any

[1] Bombay Gov. Rec., General Dept., XXII of 1874.

[2] Cyclopædia, 3rd Ed., Art. Gold, p. 1222.

[3] Memoirs Geol. Surv. India, Vol. XXX, pp. 89, 196.

"colours" and when these did occur they were extremely fine. Washing is occasionally carried on at the conclusion of the rains by washers who come from Hampi on the Tungabhadra river. The yield of the present season had, however, been so poor that they had remained for only a few days.

The source of the alluvial gold, probably here, and certainly at Doni and Sortur, must be ascribed to the auriferous reefs of the vicinity.

Reef Gold.—Many of the outcrops of quartz reefs in the northern portion of the Gadag Band are honeycombed with old workings. These, so far as is known, were first noted by Lieutenant Aytoun in 1852, but it is evident that he did not at that time ascribe to them any great age nor indeed suspect them to be the work of the ancients. Aytoun describes[1] a group of 22 ancient pits at the top of a hill of red schist called Julgurgood (Gold Washer's Hill) and lying about 5 miles from Sortur. His description of the locality is extremely indefinite, but so far as can be gathered, from the accompanying sketch map, he refers either to the Sangli old workings or, less probably, to those in the neighbourhood of Venktapur. The pits were 18—25 feet deep, and three to four feet in diameter. The natives knew nothing about them, but yet had a nebulous tradition that in bygone days gold was extracted from the rocks by the process now adopted in the manufacture of iron, that is, by breaking the ore into small pieces or powdering it, and smelting in a furnace.[2]

Aytoun was further told that "in the central range of the Kappat Guda there are two hills bearing the names of Great and Little Gold Mountains."

In one place he noted the heaps of broken quartz left by the ancient prospectors. Of the period of the excavation of the old workings we have neither the history nor does any tradition remain, but it is almost certain from reasons that will be dealt with fully when describing the Maski Band containing the Hyderabad gold mines (No. II of this series), of which area we do indeed possess some fragments of ancient history, that they at the very least antedate the thirteenth century. The old workings are exceedingly numerous in the neighbourhood of, and west of Kabulayatkatti, but unless their position is pointed out they are with difficulty discerned by the untrained eye. Generally nothing more than a slight depression with grass somewhat greener than that of the surrounding country,

[1] Trans. Bomb. Geol. Soc., Vol. XII (184), p. 2.
[2] Loc. cit., p. 5.

and with often a small coarse bush growing in the depression, serves to mark the site of an old pit that may be 80—100 feet in vertical depth. Many of the ancient pits are sunk within a few feet of each other, and in one case at Kabulayatkatti four pits occur within a radius of ten feet. The probable explanation of this apparent waste of labour lies in the ancient method of breaking the quartz,—by heating with fires, and suddenly dashing cold water on the heated rock. For effective combustion, two shafts—a downcast and an upcast—at least are necessary and the greater the number of connected shafts the more easily ventilation is controlled. Moreover, since Indian customs change but little through the ages, it is at least reasonable to suppose that each family worked independently and had each its own complete system of shafts.

The eye soon becomes sufficiently trained to discern also the low rounded heaps of debris that are scattered over the hill sides and that represent the worthless quartz broken in the examination for gold. It is interesting to note that these tailings heaps are not prominent in the neighbourhood of the more important deep old workings (as those at Kabulayatkatti, from whence in days long bygone at least 40,000 tons of quartz have been removed, finely crushed and washed), but are found more often in the neighbourhood of quartz veins that show no pits or excavations whatever. For the ancients thoroughly appreciated, or rather had forced upon them by existing conditions, the initial prospecting maxim that is inculcated, too often in vain, by the history of every modern gold-field, *viz.*, that in exploration of a quartz vein length is preferable to depth : or, in other words, that if quartz is not payable or nearly so at the surface, it is, save in most exceptional circumstances, a violation of mining economics to look for better values below. From the disposition of the old tailings heaps, and mainly from the utter hopelessness of some of the reefs attacked by the ancients, it would appear that the debris is the work of widely separated generations, the last lacking the skill and knowledge of the true gold-miners and possessing only the tradition of their work in a given area. It is certain that so long as the tradition of gold remained there would be no lack of prospecting, for of the keenness of the search for precious metals and precious stones, even in comparatively recent times when foreign trade with India, bringing gold and gems, had assumed large proportions, we get a glimpse from Tavernier, who, writing about 1665, states[1] that the Nawab Mir Jumla had impressed 12,000 men for

[1] Travels, Ed. Ball, Vol. I, p. 288.

a year to prospect for diamondiferous ground in the neighbourhood of Gandikota in the Kadapa District; and, further, that when he visited Kollur [1] (Coulour) in that year no less than 60,000 people—men, women, and children—were at work extracting diamonds from strata that are nowadays considered too poor to work.

The soft and easily excavated surface argillites of Kabligatti considerably facilitated the mining operations of the ancients. They sunk numerous small vertical shafts, four feet square, to the dip of the reefs, often not cutting the vein until the shafts were 80 feet in depth. The reefs were then followed on the underlie with great assiduity, and so far as they have been explored at Kabulayatkatti, the old workings reached a depth of at least 300 feet. Assays from old pillars left in the workings show that some at least of the quartz worked was worth 1½ oz. per ton. Deeper exploration was prevented probably by the influx of water. That the change from decomposed to harder argillite was in itself no obstacle is clear from the fact that at Hatti in the Nizam's Dominions, old workings in an immensely harder rock reached a depth of 620 feet.

Abundant relics of mills for crushing quartz exist, and afford perhaps the most valuable clue to the present day prospector of the vicinity of auriferous reefs. The mills may be separated into three divisions. The first of these were essentially rock breakers (Plate 10), in which the quartz was crushed to the size of a walnut. They are depressions about six inches in width and four inches in depth excavated by the process of pounding on any hard rock convenient to the reef. Where there was no hard rock in the immediate neighbourhood small boulders were brought from a distance to serve first as anvils and, with continued trituration, finally as mortars. Where water was also available hundreds of mortars are often grouped together, as along the diabase dyke half a mile W. S. W. of the Sangli mines, and in the quartz schist band one mile N. N. W. of Nagavi village. In the latter place no less than 218 are closely packed together on a single exposure of quartz schist (Plate 11). Into the mortars there fitted rude stone pestles 8—9 inches long and sufficiently thick to be conveniently grasped in the hand. They show no signs of shaping and are generally found with a concavity at each end showing that when one end became too broad to reach the bottom of the mortar, the pestle was reversed.

The second class of crushers consists of huge boulders rocking to and fro in depressions in a hard bed rock. These are best seen near

[1] Records Geol. Surv. India, Vol. XXXI, p. 68.

the Sangli mines and at Kabulayatkatti. A large crusher will measure 2½ feet long, 1½ feet wide and 1½ feet deep and will weigh nearly 15 cwts. An average size weighs about 6 cwts. Beneath these the broken quartz from the mortars was placed and crushed by the mere weight of the stone as it was rolled backwards and forwards. The same contrivance is used at the present day for crushing *kankar* for lime, in which case the reciprocating motion is produced by two women sitting on opposite sides of the stone and alternately pushing with the feet. The work was probably not arduous, since a crusher of about 4 cwts., being replaced in its bed, was found to be easily set in motion with one hand. Though primitive, these reciprocating crushers are extremely effective. The third form of grinding stone is far from common in this area, though it was the only one found in the ancient workings of Singbhúm in Chota Nagpur.[1] In this case a small stone was taken in the hand and rubbed to and fro along a broad groove in a larger stone. It was probably adopted only when very fine grinding was required. The best example seen of the lower grooved stone lies at the door of a shrine to the east of Nabapur village.

The modern history of the gold reefs of the Gadag Band dates from 1861 when C. Le Souef commenced his prospecting operations. He appears to have entirely overlooked the Kabulayatkatti reef and the ancient workings, probably devoting most of his attention to alluvial gold. He, however, sunk several pits on apparently barren reefs some distance east of Attikatti.

Mr. Foote, who visited the field in 1874, and described in detail the features of the Kabulayatkatti reef (his "Huttee Kuttee" reef), may be regarded as the true discoverer of the auriferous quartz reefs, for, as already stated, it was his descriptions that induced the actual pioneers, Messrs. Huddleston, Puzey, and Oliver, to commence prospecting operations about five years ago. After prospecting for some time the Dharwar Gold Mines, Ltd., with a capital of £30,000, was formed to acquire a two years' option over four blocks, which were to be worked together with other already acquired leases in the neighbourhood. The result of these explorations has been considered sufficiently promising to justify the formation, to work the four option blocks, of the Dharwar Reefs Company with a capital of £170,000 of which £70,000 is available for working capital.

[1] Records Geol. Surv. Ind., Vol. II, p. 75.

A second company, the Sangli Gold Mines, Ltd., with a capital of £75,000, of which £4,000 in cash and £18,750 in fully paid shares is purchase money, was formed in 1902, to work the reefs indicated by the ancient workings south of Attikatti and just within the boundaries of an outlying portion of the Sangli State.

The Gold-fields of Dharwar, Ltd., are prospecting a series of reefs with abundant old workings at Hosur, four miles west of Kabulayatkatti. Little progress has been made up to the time of writing,[1] but the developments, so far as they have gone, are considered to be encouraging.

Numerous leases have been taken up in the neighbourhood of these mines but very little actual prospecting work has been done on the majority, the intention of the lease-holders being obviously to await the result of the operations in the pioneer mines.

Reefs and old workings.—When commencing the survey of the area it was proposed to mark on the accompanying maps the positions of the various quartz reefs met with in the course of the survey. These were, however, found to be so bewilderingly numerous that their delineation would have entirely obscured the geological mapping and could have served no useful purpose. The chlorite schists, argillites, mica schists and hornblende schists are especially favourable to the development of quartz veins, and in the case of the two last it is often impossible for acres together to obtain an exposure of the underlying rock owing to the prevalence of the quartz "shoadings," or fragments shed from veins. Only those reefs therefore, along which extensive old workings have been traced, are shown in the attached map.

Two varieties of quartz occur, a blue diaphanous to almost black quartz similar to that at Kolar and at Hatti, and a white opaque quartz, All the old workings yet found have been associated with the latter. So far as the data at hand goes, the blue quartz may be said to be restricted to the metamorphosed igneous rocks—the hornblende schists, felsites, etc.—while the white quartz is found everywhere. Under the microscope the chief distinction between the two varieties is the state of strain in which the component quartz grains of the former are found. So far has this gone that in places relief has been found by the development of shearing or gliding planes. The blue or black colour of the quartz appears to be due to the absorption and internal reflection

[1] May, 1905.

of light occasioned by these shearing planes and not to the presence of colouring matter. The white quartz on the other hand shows no more than the normal strain figures shown by the quartz veins of undisturbed regions. The latter is therefore much the younger and is certainly to be connected with the thermal activity occasioned by the intrusion of the diabasic and doleritic dykes.

The most northerly of the old workings are along a N. N. W.—S. S. E. line half a mile N. W. of Nagavi village and only four miles S. W. of Gadag. These have not yet been opened up. Half a mile to the east, at the top of the main ridge north-east of Nagavi, is a series of old workings in the banded hæmatite quartzite. These have presumably been opened up for iron ore, but it must not be forgotten that the banded hæmatite quartzites of very similar rocks in Western Australia are decidedly auriferous, especially where they are crossed by later veins or by faults. It is true that numerous pannings of the banded quartzites in other places gave the present writer no result, but they should, nevertheless, always be tested by the prospector.

From Nabapur through Kabulayatkatti and Attikatti to beyond the Sangli Gold Mines, a distance of about 8 miles, there is an almost continuous chain of old workings on a series of more or less parallel reefs. It is in this band that the most important reefs have been discovered. Some old workings opened up by the Dharwar Gold Mines immediately north-west of Nabapur are notable as containing dark brown very finely developed crystals of manganite, the hydrated sesquioxide of manganese. The occurrence is very limited and is only of mineralogical interest.

The main Kabulayatkatti old workings commence on the bluff south of the village and extend continuously for a mile further south. There are three main parallel reefs all having been worked by the ancients and all dipping at 50°—60° to the east. The most easterly has apparently the steepest underlie, dipping indeed with the country, which, as has been noted in another place, steepens on approach to the intrusive diabase which lies to the east. So far the greatest amount of work has been done on the middle or No. 2 reef, an inclined shaft having been sunk to a depth of 436 feet and a vertical (No. 22) to a depth of 353 feet, with levels at various points, most of which down to the 300 feet level disclosed old workings. The reefs as a whole appear to be permanent but vary locally both in width and in value, ranging from zero in either case up to 3 feet 6 inches and 3 oz. 15 dwts. per ton.

Their most characteristic feature in depth is their association with graphitic "pug," or kaolinic vein matter. The carbon is obviously present in small quantity, but is nevertheless sufficient to give the hardened pug a deep black colour and lustrous surfaces. Two sources for the graphite are possible. The first, from the downward infiltration of carbonaceous matter, such as is contained in large quantity in the black cotton soil at the surface, the second, and almost certainly the true source, from the adjacent argillites. These in depth are black, fine-grained rocks and the great development of iron pyrites in them certainly points to the presence of some such reducing agent as carbonaceous matter. The development of iron pyrites has been especially active in and near the graphitic reefs. The concentration of graphitic matter along certain reef lines perhaps represents not so much continued infiltration from the adjacent country as an original highly carbonaceous band. It is noteworthy that the Sangli reefs, the only others in which graphite has been found, apparently occupy exactly the same horizon in the argillites as do the reefs at Kabulayatkatti and while the reefs are certainly discontinuous the ore belt stretches from one place to the other. At the same time it must be remembered that graphite was not met with in these mines until a depth of 200 feet was reached and that these are the only two that have reached that depth. Should, however, other mines, as at Hosur, fail to meet with graphite in depth, the carbonaceous belt theory may be considered to be fairly well established.

The evidence at present available is not sufficient to justify the formation of any hypothesis with respect to the deposition of the gold in the Kabulayatkatti veins. How far the carbonaceous matter itself and how far the ferrous sulphate derived from salts by the reducing action of carbonaceous matter were severally responsible for the precipitation of the gold must remain an unsettled point until more of the reef has been exposed and until a more detailed examination than was possible in the present case has been made.

In the Sangli mines (Plate 13), while the ancient surface workings are quite as extensive as those at Kabligatti, the same depth does not appear to have been reached, the old workings on one reef having been bottomed at 170 feet. Here as at Kabulayatkatti there are three reefs also dipping east, but much less steeply, their inclination being only 35°—40°. The old workings lie immediately to the west of a N. S. diabase dyke and to the east of one of the few grit bands met with in the argillites. The main work at Sangli has so far been devoted to the sinking of two shafts. each east of the dyke, to intersect the reefs in depth.

Work is also being done on the eastern line of old workings at Hosur, three and a half miles W. of Kabligatti, by the Gold-fields of Dharwar, Ltd., but has so far been confined to sinking in the old workings. The country rock is here a more or less micaceous schist which gives place to talc and chlorite schist in the immediate vicinity of the quartz-veins. Ancient workings have also been disclosed at the following places: one mile S. W. of Nabapur: the same distance S. W. of Kabulayatkatti: half a mile W. of Venkatapur: and north of Dindur.

South of Sangli mines, as far as the Mysore boundary, diligent search failed to reveal ancient workings, nor were enquiries among the inhabitants for any signs of these more successful. *En passant*, it may be mentioned that it is useless to ask for information from the natives concerning crushing mortars (the holes in the rocks resulting from the crushing of quartz) as such, but if enquiry be made for rock holes made by children in ancient times, their location will be pointed out if any such exist in the neighbourhood. For so completely has the memory of the ancient industry passed from the minds of the inhabitants that the tradition has arisen that these mortars are the work of the children of a bygone herculean race, who, while idly watching their flocks, worked these holes into the rock in order to play a game not greatly dissimilar, so the natives say, to that for which the village children of the present day excavate a series of small holes in the hardened earth.

There is, however, one exception to the statement that no old workings were found south of Sangli. In the small hill overlooking a newly formed tank, ¾ mile S. E. of Devagondanahalli in the Bellary District, Mr. Foote[1] noted numerous old pits in a pebbly conglomerate, together with a couple of small platforms such as may have been used for sorting ore. Rather extensive old stopes in a similar rock were found by the present writer 3½ miles further S. S. W., at the southern end of the great pebbly conglomerate ridge running up into the Mallapan Guda. Numerous samples were taken from the Devagondanahalli hill (Dagunahalli of Foote); from south of Nagati Basapuram; from a similar pebbly conglomerate east of the Jajkul Guda still further south, and were crushed and panned. In not a single case was a colour of gold or even any sulphide obtained. Mr. Foote supposed that ancient prospectors, struck by the resemblance of these pebbly conglomerates to the diamondiferous beds of Bana-

[1] Memoirs Geol. Surv. India, Vol. XXV, p. 87.

ganapalli in the Karnul District, had explored them for diamonds. This supposition is probably correct. Nevertheless, owing to the proximity of the Konganahosuru alluvial gold, the pebbly beds of the Jajkul Guda deserve a more thorough trial than they have received during the present reconnaissance. Owing to the great scarcity of water in the neighbourhood this trial is possible, except with great labour and loss of time, only during or immediately after the rains.

Old workings found in the hæmatite quartzites near Chik-Vadvati and near Mundvad were obviously for gun flints and are supposed to have been excavated for the armies of Hyder Ali and Tipu Sahib.

Manganese.

Manganese occurs in small quantities in many of the banded hæmatite quartzites. It appears to be best developed along the main ridge lying immediately east of the Chik-Vadvati valley. The rocky outcrops of the ridge as far north as the fault line shown on the map are stained black with manganese oxides. This locality was first mentioned by Newbold[1] who visited the place in 1839, being led thither by the report of coal. The chief locality lies in a small gorge in the hills two miles east of Chik-Vadvati (Wodoorti of Newbold). The country is a fissile chloritic schist dipping 40° E. N. E. and the manganese is contained in a broad band of hæmatite quartzite in the chlorite schist. The dip of the quartzite band is not evident but is probably that of the country.

A considerable amount of work has been done here since 1903 by the Bombay Co., Ltd., whose attention was directed to the spot by the above-mentioned report of Captain Newbold. Numerous pits were sunk and two levels driven for 70—80 feet to intersect the band in depth. The result of the two years' prospecting has been most discouraging. The ore is very low grade and moreover contains a very high percentage of silica and of phosphorus. The average of ten of the best assays is no more than 50 per cent. oxide, equivalent to, at the very most, 32 per cent. metal. Moreover, the two levels driven to the quartzite showed at a depth of 15—20 feet only 30·7 and 31·9 per cent. oxide, respectively, indicating a correspondingly high rise in silica contents. Even were the manganese oxides present in ordinarily payable quantities, the mining expenses in working it out

[1] Roy. As. Soc., Vol. VII, p. 212; Madras Jour. Lit. and Sci., Vol. XI, p. 44.

of the hard quartzite would be exceedingly heavy and would preclude profitable working.

Other manganiferous beds met with during the course of the survey were on the hill overlooking the temples east of Hamigi on the Tungabhadra river, and at the northern end of the ridge two miles S. S. W. of Hamigi. In the first mentioned locality pieces of pure ore 4 to 5 pounds in weight may be broken off the face of the rock, but this deposit is merely a surface incrustation and is apparently of no economic importance.

There seems to be little probability of manganiferous beds of value occurring in intimate association with the banded hæmatitic quartzites. The inevitably high percentage of silica and the difficulty of working combined must inevitably exclude these from the list of workable manganese deposits. Prospecting for manganese, if undertaken at all, should therefore be directed rather towards the schists in the hope of finding replacement beds of the mineral.

General.

As a gold-field the Gadag area is exceptionally well situated. It is at present only eleven miles from the railway, and the proposed Gadag-Yalvigi connection of the Southern Mahratta Railway will bring it within two or three miles. The field is 2,300 feet above sea-level and the climate is excellent throughout the year. In the event of greatly extended operations justifying the capital outlay a source of ample electrical power is available from the Tungabhadra river about 20 miles away. The rainfall is, however, very light and some difficulty will probably be experienced in obtaining sufficient water near the mines for large mills and works. Sites for dams have been secured, but the mines are situated almost at the crest of the main divide and the catchment areas are therefore small.

Perhaps the most interesting feature in the geology of the Gadag Band is its differentiation from the two best known auriferous Dharwar areas—the Kolar and the Hatti—in the occurrence of its gold-quartz veins in argillites. In this, however, it resembles other gold-fields in the same band many miles to the south in the Mysore State. The auriferous hornblende schists of Kolar and of Hatti do occur in the Gadag Band and do furnish veins of blue quartz, but these have been little prospected. It would moreover appear that the Kabulayatkatti and Sangli veins are of the same age as the little exploited white quartz veins of the two former fields, and like them owe their origin to a recrudescence of thermal activity due to the intrusion of the diabasic and doleritic dykes that are common on all Dharwar fields. The blue veins are regarded as being much older and as being produced on the final consolidation of the magmas that are now hornblende schists.

The point has no practical bearing whatever on the possible economic value of the field, for if there is one feature more than another that an examination of many gold-fields and a close study of the literature of more has brought into vivid relief, it is that no safe deduction as to the value of any gold-field, or indeed of any gold vein, can be made from the data furnished by an adjacent field or vein. The processes of gold deposition are too complex and our knowledge of them too scanty to admit of rules, and each field must be left to laboriously work out its own salvation. Indeed Nature has at her command such a variety of possible combinations that the wonder is, not that all fields are not alike, but that any two should show points of similarity.

We do, it is true, catch an occasional glimpse of fundamental principles, as in the generally auriferous character of the Middle Tertiary basic andesites, and coming nearer home, in the restriction of gold in Southern India to the rocks of the Dharwar series, yet the glimpse is at best a fleeting one and serves but to accentuate the prevailing obscurity of uncorrelated and therefore incomprehensible facts. It follows therefore that no possible matrix of gold in a new Dharwar field should be left unprospected. Quartz-veins, white and blue, banded quartzites, boulder beds, and pebbly conglomerates—all are possible hosts of gold. Nor should any pyritous "lode formation" along a line of reef, though at the spot containing no quartz, escape assay.

While the general geology of the Dharwarian series is identical with that of the "Auriferous Series" of Western Australia, and while the features of the majority of its veins (and especially those in the hornblende schists) correspond very closely with those of that State, we have yet, in order to find a vein occurrence similar to the Kabulayatkatti-Sangli belt, to go much further afield to the quartz veins in the graphitic zones of the southern Appalachian gold belt of Alabama, Georgia, and South Carolina. There we find similar argillites crowded with pseudomorphs of limonite after pyrites, a similar general lenticular disposition of the quartz with often parallel and overlapping lenses, and similar minor irregularities within a well defined and graphitic vein belt.

In illustration of the tendency of gold to deposit in aberrant forms in metamorphic schists, such as those under consideration, the case of the Haile mine in South Carolina may be appropriately cited. There the auriferous deposit is wholly devoid of quartz and is merely a pyritous impregnation of the country rock (mica schist) 10 feet or more wide. One boundary of the deposit is determined by assay, the other is formed by the diabase dyke, the intrusion of which is responsible for the ore deposit.

List of Plates.

THE ABANDONMENT OF THE COLLIERIES WORKED BY THE GOVERNMENT OF INDIA AT WARORA, CENTRAL PROVINCES. BY R. R. SIMPSON, B.SC., *Deputy Inspector of Mines in India.*

ON the 28th March, 1906, a serious subsidence took place at the Government Collieries at Warora, and as a consequence the mines have been permanently shut down.

The Warora coal area is situated in the Chanda district, 62 miles south of Nagpur, Central Provinces. It forms part of the Wardha Valley Coalfield, which stretches for 72 miles along the valley of the Wardha river, and covers some 1,600 square miles. The field was geologically mapped by Mr. T. W. H. Hughes,[1] of the Geological Survey of India, between 1870–76, and the same officer superintended the carrying out of an elaborate scheme of coal-boring tests. The result of his investigation was the establishment, in 1873, of the collieries which, from that date till the present year, have been continuously carried on by the Government of India.

The workable area proved by Hughes was ¾ square mile, and he estimated that it contained some 20 millions of tons of coal; whilst he considered the southerly extension of the basin probable. Between 1891 and 1893 efforts were made to prove this extension by means of borings, and the assistance of the Geological Survey was sought for and obtained. The borings were, however, unsuccessful.

The Warora coal is distinctly inferior to the product of the Bengal coal mines. It contains high percentages of moisture and inorganic matter, and is low in carbon content. It is friable, contains more sulphur than the average coal, and is liable to spontaneous combustion. There are two coal seams, respectively, 12 and 15 feet thick, separated by shales varying in thickness from a few inches up to 14 feet. The depth from the surface varies from 63 to 285 feet and the dip of the strata is 4°.

The working of the colliery has been much hampered by the necessity for heavy pumping operations. There have been a large number of underground fires due to spontaneous combustion, and it

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[1] *Memoirs Geol. Surv. Ind.*, XIII (1877).

has been stated that 70 per cent. of the proved area was dammed off in the course of subduing the fires.

The total amount of coal obtained from the mines was about three million tons, the largest output being mined in 1902, in which year 153,336 tons were raised. The capital expenditure has been heavy and for many of the years of its career the profits of the venture were small. As the result, however, of able management, satisfactory dividends have been earned for a number of years past.

Shortly after the occurrence of the subsidence referred to in the first paragraph, the mines were visited by Mr. W. H. Pickering, the Chief Inspector of Mines in India, and that officer after making a complete investigation of the situation recommended that the collieries should be closed down. Shortly afterwards orders to abandon the working were issued by Government. For some years past operations had been confined to the extraction of coal pillars, and in any case the mine could not have been kept working for more than about six months longer.

In the report of the Chief Inspector of Mines it is mentioned that there have been serious subsidences previously, and the area of the newly subsided ground is said to be about 15 acres. By the fall of such a large extent of the roof, a strong air-blast was caused, and a workman was injured by its effects. In the opinion of the Chief Inspector the subsidence was directly due to defects in the method of working. Instead of extracting each seam separately, and allowing a considerable interval of time to elapse between adjacent workings, both seams were mined at the same time. The coal pillars also were too small. The result of this policy was that the workings were very unstable, and the isolation of fires rendered extremely difficult. These mistakes, however, were made many years ago, and the present management cannot be considered responsible.

In anticipation of the exhaustion of the Warora Collieries, shafts were put down at Bellarpur, some 38 miles further down the valley, where a seam of satisfactory coal has been cut through. The machinery and plant are now being transferred from Warora to Bellarpur, and on the completion of the railway extension now in progress, coal raising will be commenced. It is probable, therefore, that the deficiency in the coal outturn of the province will be merely temporary.

MISCELLANEOUS NOTES.

Preliminary note on the Trias of Lower Burma.

TRIASSIC rocks were first discovered in Lower Burma by Theobald who described them in the *Mems. Geol. Surv. Ind.*, Vol. X, Part II, pp. 127-137. Amongst the rocks regarded as Triassic by Theobald the hard black limestones alone yielded fossils identified by Stoliczka as *Halobia Lommeli.* The occurrence of these Triassic rocks is noticed in the first edition of the *Manual of the Geology of India*, Vol. II, pp. 710, 711, but in the second edition (p. 145, footnote) it is stated that the fossil was wrongly identified, and that the rocks are not Triassic but Tertiary. The same view is expressed in the Annual Report of the Geol. Surv. Ind., 1892, p. 9, from the work done by Mr. Datta in the Arrakan Yoma. In the Annual Report for 1900-1901, pp. 19, 20, the view is expressed that if Triassic rocks do occur, they are probably as Klippen in newer deposits.

A search in the Museum brought to light one of Theobald's original specimens, a hard black limestone with numerous lamellibranch casts and fragments. Careful development of one of these casts shows that the fossil is really an *Halobia*, which is distinct from any described Indian species. In the same block are some *Monotis* like shells and an *Avicula* which is very close to *Avicula* (?) *Girthiana*, Bittner. (*Pal. Indica, Himalayan fossils*, ser. XV, Vol III, Pl. VII, f. 17, 19.)

Mr. Datta's collection from the same district contains a number of blocks of a hard dark grey limestone, which unfortunately have yielded no characteristic fossils. They are crowded with Polyzoa and are lithologically like Theobald's specimen, so that they may really be Triassic.

There is another collection of Triassic rocks from Burma which has so far escaped notice. It consists of a series of hard black limestone blocks crowded with fossils. The fossils are extremely well preserved specimens of *Halobia*, allied to the *Halobia* of the Arrakan Yoma, and *Monotis.* The label attached reads as follows : " Sent to Mr. Theobald by Mr. D. O'Riley from Karennee, Aug. 1864." The exact locality is not stated.

The object of this note is to point out that Triassic rocks do occur in the Arrakan Yoma and other parts of Lower Burma, although it seems probable that they do not occupy such a large area as was mapped originally by Theobald.

[G. H. TIPPER.]

Note on the Tertiary deposits of Mayurbhanj.

In these *Records*, Vol. XXXIV, Part I, p. 42, there is a note by Mr. P. N. Bose on a boring in the Tertiary deposits of Mayurbhanj. At a depth of 142 feet the boring passed through fossiliferous limestones and marls. The specimen in this office labelled as coming from that depth is a marl crowded with foraminifera and fragments of lamellibranchs. On the authority of Mr. Pilgrim it is stated that *Amphistegina* occurs in large numbers. In the hope that this *Amphistegina* might prove to be identical with one obtained during my recent survey in the Andamans I extracted a large series of foraminifera by means of an elutriator. Examination of the resulting specimens failed to reveal the presence of *Amphistegina*, all the forms belonging to the genus *Rotalia*. Through the kindness of Dr. N. Annandale I have been enabled to compare it with the recent *Rotalia Orbicularis* d'Orb., from the Arabian Sea. Although it is fairly close to that species, it is much closer to *R. Beccarii*, Linn., figured by Parker and Jones in the Phil. Trans., 1865, Pl. XVI, f. 29, 30, and in Mon. Crag Foram., Pl. II, f. 19, 20, 21. Like all the simple foraminifera, and unlike *Amphistegina*, the genus *Rotalia* has a long range in time. This species in particular is known from the Jurassic to the present day and hence it is impossible, simply from its occurrence, to draw any conclusion with regard to the age of the deposit.

[G. H. Tipper.]

On the use of Gypsum for the recovery of ammonia as a by-product in coke-making. By H. Warth. *Chemical News*, June 8, 1906, pages 259, 260.

This note gives an account of some experiments made to demonstrate the possibility of using gypsum instead of sulphuric acid for the production of ammonium sulphate from ammoniacal gas liquor, (gas water). The original liquor contained carbonate, chloride, sulphide, and other compounds of ammonia. By shaking this liquor thoroughly with plaster-of-Paris all the ammonium carbonate present is converted into sulphate, a corresponding amount of the calcium sulphate being converted into carbonate. The clear fluid is now evaporated to dryness, leaving only the newly formed ammonium sulphate and the small quantity of original ammonium chloride. This residue contained, in Dr. Warth's experiment, 80 per cent. of the original ammonia. By passing into sulphuric acid, the free ammonia evolved on boiling the original liquor, a further 17 per cent. of the original ammonia was recovered, so that by a combination of the two processes 97 per cent. of the ammonia could be recovered by means of gypsum, aided by about ⅛ of the sulphuric acid which would have been required without the use of gypsum. This is considered to be the most advantageous process, but if desired the use of sulphuric acid can be entirely obviated by treating the original liquor as before with gypsum (or plaster-of-Paris), carefully removing the sediment of calcium carbonate, and treating the clear solution with ferrous sulphate. In Dr. Warth's experiment a precipitate of ferrous sulphide was thus produced. This was filtered off and the solution on evaporation yielded 95·4 per cent. of the entire ammonia.

[L. L. FERMOR.]

G. I. C. P. O.—No. 47 D. G. Surv.—16-10-06—700.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1906. [November.

ON EXPLOSION CRATERS IN THE LOWER CHINDWIN DISTRICT, BURMA. BY R. D. OLDHAM, A.R.S.M., F.G.S. (With Plates 16 and 17.)

ON the west bank of the Chindwin, opposite Monywa, a number of small hills rise from the plain, whose pointed forms and even slopes, showing no definite stratification, suffice to show that they are not composed of the Tertiary sandstones of this region. Where touched by the route I followed they were found to consist of a hard cherty rock, not unlike some of the less typical jaspideous beds of the Bijawars. These hills are evidently composed of pre-Tertiary rock.

A couple of miles beyond Paungga bedded sandstones are seen, probably Tertiary, though unlike the typical pliocene sandstones. In a stream-bed about 3 miles from Paungga, very much decomposed volcanic rock is seen and for a mile beyond volcanic rocks continue, but are nowhere well exposed. Further on is the hill of Enjindaung composed of massive pliocene sandstone in which a number of cave temples have been excavated; this hill is really an escarpment as the ascent on the east is imperceptible, but after passing the crest there is a rapid descent to the low-lying ground towards Lengauk and Myo-gyi. On this descent volcanic ashes and lavas are seen, apparently inter-bedded with the pliocene sandstone.

The low ground from the foot of the descent, at Kaungzein, to Obo is largely covered by alluvium through which the pliocene beds rise to the surface. The high hill north of Obo is composed of hard quartzites, evidently an indurated form of the pliocene sandstone, but I saw no volcanic beds on the eastern face of this hill.

B

Where the road to Tayawgyin branches off from that to Linbonye, I saw a number of blocks of lava, andesite like the other lavas seen in this district, lying on the surface, whose origin I was at the time unable to account for; they were very probably ejected from the craters to be described further on.

Ejected blocks of lava.

Shortly after the separation of the roads an outcrop of coarse-grained granite with small-sized mica is entered on. This is very decomposed where it reaches the surface; the exposure extends for over a mile to the bed of the stream which flows down by Tayawgyin.

Granite.

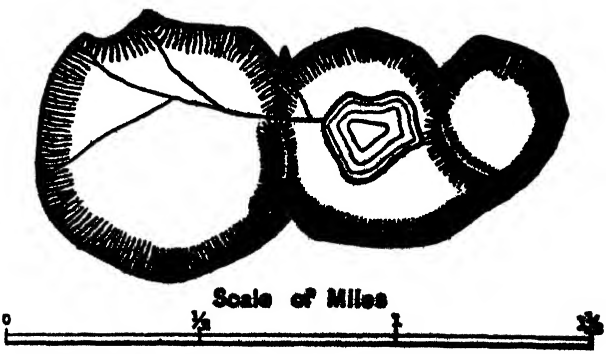
The low hills south of Tayawgyin were found to be composed of pliocene sandstones interbedded with lavas and ashes.

Pliocene volcanics.

After crossing the stream at Tayawgyin the country, as far as Leshe, is covered with volcanic ash, through which appear some exposures of pliocene sandstone. Just before reaching Leshe the track runs out on to the edge of a remarkable depression, marked, though somewhat misleadingly, on the map. It has a length of about 1½ miles and a width of about ¾ mile, and is surrounded on all sides by a precipitous scarp in which pliocene sandstones are overlaid by from 30 to 50 feet of volcanic tuffs and breccias. This depression is not only recognisable as a volcanic crater, but on further examination is seen to be a compound, not a simple, crater, being divided into three by cross ridges of volcanic ash.

Leshe pit crater.

A rough ground plan of this depression is given in Fig. 1, from



(Dotted lines show approximate exposure of pliocene sandstones.)

FIG. 1.—*Plan of Lower Chindwin crater-lakes.*

which it may be seen that there are three craters, the central, and deepest, of which holds a shallow lake of brackish water, while the easternmost, and smallest, is the newest. It is noteworthy that these cross ridges are not solely formed of volcanic ash but are composed of pliocene sandstone near their junction with the outer scarp, from which it may be concluded that this portion of the cross ridge owes its origin to the removal of the sandstones from either side.

A compound crater.

The depth of this depression is inconsiderable in proportion to its area, the central and deepest of the craters being not more than 150 feet deep, while the lake in the centre is said to be not more than 6 feet deep. The floor is at present entirely composed of débris washed down from the sides of the crater, which have to some extent been modified in shape by rain wash and the cutting back of small ravines.

Absence of crater rim.

To this same cause must be attributed the absence of anything like a definite ridge or rim bounding the depression. On every side the ground slopes gently up to the edge of the scarp, at an angle which nowhere exceeds 10° and is usually much less. The size of the ridge which originally bounded the crater may be judged from that which now bounds parts of it, that is to say, the ridges which divide the crater into three; thus the ridge formed along the edge of the central crater and separating it from the western is quite narrow and well defined. Where exposed to active denudation, as on the edge of the plateau, this would soon be removed, bringing the edge of the scarp back to the gentle slope behind the defined bounding ridge.

Mode of formation.

As the principal interest of this crater depression, which is one of a group extending for about 12 miles to the north-east, lies in its bearing on the theories of formation of pit craters and crater lakes, it will be simplest to describe the observations made on it with reference to those theories.

Crater lakes and pit craters have been attributed to three different causes,—(1) to the widening of the crater by the action of molten lava in gradually melting and dissolving its sides, as is supposed to have been the case with the Hawaian craters, (2) subsidence and (3) explosive eruption.

The first of these may be rejected in the present case. There is not the slightest trace of a lava flow, and a remarkable absence of evidence of heat, either in the material ejected from the crater, or on the sandstone of its sides. These are reddened at their junction with the overlying ashes and on the slopes below a similar reddening is seen in places, but how far this is due to the heat of the volcanic eruption, or how far merely to the redness produced by weathering it is difficult to say. In the material ejected from the crater are numerous fragments of lava, but it is rare for these to have either the rounded form, or the scoriaceous surface, of a typical volcanic bomb; all the larger fragments, and nearly all the smaller, are angular—often with quite sharp corners—showing no sign of fusion, and evidently produced by the breaking up of a cooled and thoroughly solidified lava flow.

The hypothesis of formation of crater lakes and hollows by subsidence, seems to be attributable to the usually insignificant bulk of the material contained in the surrounding ridge, as compared with the volume of the cavity. In this case, there being no surrounding ridge at all, the argument might seem to be of still greater weight, but if we compare the volume of the cavity with that of the material ejected the argument falls to the ground. Assuming a hollow 1 mile in diameter and 150 feet deep, quantities which roughly represent the actualities of the case, the materials removed would be sufficient to form a deposit of 20 feet in thickness round the rim and thinning out to nothing at a distance of 2 miles. In the case of the Leshe crater the deposit is from 30 to 50 feet thick at the edge of the crater and retains an appreciable thickness at three miles away. It is evident that the material ejected is more than enough to fill the hollow, so that we have no need to appeal to subsidence.

There remains Scrope's hypothesis of explosion craters (*Volcanoes*, 2nd ed., p. 217). It is not necessary to consider whether the mechanism of the explosions, as given by him, is the correct one, as, apart from any question of this, the expression may be taken to imply that the crater is due to a single eruption of great violence but short duration.

Explosion craters.

The absence of any trace of a subsidiary cone in the centre of either of the three confluent craters is sufficient evidence of the cessation of volcanic activity with the great eruption which formed the crater, while the size and form of the ridges separating them is proof that the eruption, by which the crater was formed, was not preceded by a long series of eruptions and the building up of a volcanic cone. Had this been the case the dividing ridges would probably have run across the depression much more on a level with the crest of the surrounding scarp than is the case; moreover, had a volcanic cone been built up on the site of the central crater, of which the ridge separating it from the western one is merely a remnant, it is difficult to believe that the western hollow would not have been more completely filled up than is the case, nor would one expect the ridge to be so well defined on its outer side. On the other hand, in the case of a single eruption of great violence, it is conceivable that the matter erupted would be ejected with great violence and scattered to a distance, only that portion whose velocity was checked by friction against the sides falling in the immediate neighbourhood of the edge, and forming thereby a well-defined ridge of small dimensions.

Nature of ejected material.

The nature of the material which has been deposited on the surrounding country is further evidence against the accumulation of a great quantity of volcanic material previous to its dispersion. Though I have, for convenience, described this as volcanic ash, or tuff, a closer examination shows that it is largely, in many cases more than half, composed of sand derived from the pliocene sandstones, while the coarser layers contain numerous quartz pebbles, sometimes in such abundance as to give them the appearance of a stream deposit. Fragments of silicified wood are not uncommon, and among the larger fragments are some of indurated sandstone or conglomerate, whose hardness is not necessarily due to heat since local siliceous induration of the sandstones is not uncommon. Apart from these fragments all the blocks of over 3 or 4 inches in diameter consist of volcanic rock, almost all of andesitic lava, and these blocks, as has been noticed, rarely show any sign of fusion on their outer surface. They occur in the manner of volcanic bombs in the beds of tuff, but fragments showing the rounded form and scoriaceous outer surface of the typical volcanic bomb are very rare, and, so far as I saw, only of small size.

No signs of heat.

This absence of any sign of great heat, and the confused condition of the ejected blocks, makes it probable that the eruption was of the nature of that of Tarawera in 1886, in which, although the ejected débris is said to have been hot enough to set the vegetation on fire in places, the eruption was regarded by Dr. Hector as a hydrothermal phenomenon of not deep-seated origin, and in which the eruption so far differed from ordinary volcanic eruptions that no illumination of the ascending steam clouds could be observed at night, pointing to the absence of any mass of molten rock in the neck of the crater, and to a temperature which could not have exceeded a dull red heat (New Zealand Geol. Survey Rep., 1886-87, p. 249).

Crater of Twin.

Two miles north-east of Leshe lies the village of Twin, on the edge of another pit crater, fully 1¼ mile in diameter, with a large lake at its bottom. For three-quarters of its circumference the edge of this pit presents the same characters as that of the Leshe crater, that is to say, pliocene sandstones are overlaid by volcanic material, and from the crest of the scarp the ground slopes gradually away on all sides. On the north, however, the aspect is different; here a hill rises to a height of about 400 feet above the level of the lake, and the section of this, exposed by the removal of part of it by the formation of the crater pit and the subsequent erosion of streams cutting back into it, has exposed a section which shows it to be an old tuff cone. Part of the original crater appears to be still traceable, though its original form has partly been worn away and partly rounded off by the addition of a deposit of material ejected from the more recent pit craters. This hill is shown on Plate 17, in which the outward slope of the layers of tuff, and the concave bedding in the old crater, can be distinguished; the spurs running down towards the lake are composed of ash beds dipping away from the old crater, and on this side of the lake no pliocene sandstones are seen below the volcanic ash. We have here an old volcano, active during pliocene times, which has preserved some trace of its original outline.

Taungpyauk.

On the other side of this hill is a group of craters and a crater lake containing two distinct craters, of which the nearer and shallower is judged from the structure of the ridge to be the newer. A third crater is slightly excentric to this newer one, by which it has been almost obliterated. The edge of the crater pit is cut out of the plain of pliocene sandstones, and there is no defined ridge bounding the crater.

The rock cliff which rises on the east of the Taungpyauk lake is composed of andesite, similar to that of Poppa. From its thickness —there is fully 120 feet cleanly exposed—and its massive character it seems to form part of a volcanic neck. To the east and south-east of the craters are low hills, composed of volcanic rock, mostly andesitic lavas, which retain no trace of their original form but have been carved by denudation and, on the outer side, descend abruptly to the plain of pliocene sandstone covered by volcanic ash. Though the rocks of which these hills are composed are of volcanic origin, the hills themselves show no trace of their original form, and their present shape is entirely due to subaërial denudation very slightly masked by a covering of ash erupted from the pit craters. It is evident that the volcanoes of this neighbourhood—which had been active in pliocene times—had become extinct and much worn down by denudation before the formation of the pit craters.

Variation in the material ejected.

A noteworthy feature of the material ejected from these craters is the variation in its composition. Where they are carried out of, and bounded by, the plain of pliocene sandstones, the material resembles very closely that found on the edge of the Leshe craters, but where they are bounded by the old volcanic rocks the admixture of sandy material is much less, while fragments of lava are extremely abundant, and, as this rock is much less easily disintegrated than the sandstone, the ejected material is much coarser-grained. On the north-east of the Taungpyauk crater, for instance, where it has been cut out of the massive flow or neck of andesite, the ashes are full of blocks of this rock, many of large size, and, as at Leshe, angular and showing no signs of fusion.

Twin, E. of the Chindwin.

On the opposite (east) side of the Chindwin are the remains of another old volcano, which, so far as may be judged from the extent of its ashes, must have been of much larger size than that west of the Chindwin, though now, like it, reduced to a group of low hills intersected by stream valleys, whose rounded outlines point to a long period of uninterrupted action of subaërial denudation. At the northern limit of these hills is a crater-pit and lake, deeper than any of those west of the Chindwin, being about 300 or 350 feet from top to the level of the lake. My acquaintance with this lake is confined to a single visit.

On the north the bounding ridge is composed almost entirely of a volcanic plain, but underneath it are andesites whose upper surface has an undulating form, like that of the hills to the west. This part of the circuit of the lake has an even sweep and has evidently preserved with but little alteration the form impressed on it by the eruption which formed the crater. The aspect of this part of the surrounding wall is very different to that of the south-western side of the hollow. The difference appears to be due to the position of the crater on the margin of the group of hills; after its formation the northern side, forming the actual watershed, has remained but little affected by the rain which fell on and percolated into it, while on the other side the rim of the crater probably formed a barrier across valleys draining from higher ground behind it. Here the rainfall, instead of sinking into the ground and escaping gradually by percolation, would accumulate on the rocky floor, and the supply would be increased by that falling on the higher hills behind; the crater rim opposite these valleys would, consequently, be more liable to removal by denudation than on the opposite side of the crater, and the difference between the present aspect of the two sides accounted for. My examination of this crater was not, however, sufficiently extensive to establish or refute this explanation of the difference in form of its opposite sides.

Probable change in river channel.

It may be well to record what appears to be a change in the course of the Chindwin river by the eruption which produced this crater. At Shwezage, the Chindwin, whose flood channel is usually from a mile to a mile and a half broad, is confined between cliffs of volcanic ash, not much more than 60 yards, at an eye estimate, apart. These ashes dip southwards and are indurated into a hard rock, quite different to the loose texture of the matter ejected during the last eruptions, and it is to this hardness that the narrowness of the channel at this point is primarily due. But, though the local hardness of the rock forming the banks at this point is the direct cause of the narrowness of the channel, this narrowness, and the resulting violence of the current at this point when the river is in flood, shows that the channel here is newer than elsewhere, in other words that there has been a recent diversion of the course of the Chindwin.

Now if we turn to the country south of the Twin hills, we find the southern side of these hills bounded by an open plain of nearly a mile in width, beyond which there is an abrupt rise to an undulating plateau composed of volcanic ash and breccia and the northern face of this plateau shows, in ground plan, a succession of curves of the same order of magnitude as those which mark the edge of the channel of the Chindwin. At Wunbo, too, where this depression joins the present channel of the Chindwin, the low ground occupies a semi-circular area behind the bluff facing the Chindwin. The map shows a considerable stream occupying the stretch of low land, but this stream is an invention of the map-maker. As a matter of fact there is no defined stream channel except close to the Chindwin river, and no stream at all adequate to the formation of this low ground, which has evidently been cut down by a stream of considerable volume. A possible explanation is that this low ground marks the former course of the Chindwin river, whose channel was blocked by the ejections from the Twin crater, and the waters thereby diverted to a new channel over lower ground to the west of the Twin hills. A fuller examination of the ground is, however, required before this hypothesis can be accepted, and it is only mentioned as a hint to be followed up in future survey.

Basic ashes.

The volcanic ashes which form the plateau, south of the low ground just referred to and north of the village of Lemyo, contain some beds of a very basic nature, being full of olivine, hornblende and very dark-coloured biotite. These ashes belong to the late eruptions of the old volcano and have no connection, so far as I could make out, with that by which the present crater pit of Twin was formed.

Crater pits not visited.

I was informed that there are two more crater pits about 4 miles to the N.E. of Twin; they are marked on the ¼ inch map and are evidently of the same type as those at Leshe, *i.e.*, blown out of the plain of pliocene sandstones.

General considerations.

There are certain considerations arising out of the group of pit-craters described above. The first of these is the number of them, amounting to 10 and possibly 11 distinct rents, distributed as follows :—

2 near Ôkaing (not visited).
1 at Twin, east of the Chindwin (Twinywa of the map).
3 at Taungpyauk.
1 at Twin, west of the Chindwin.
3 at Leshe.
1 more to the west of these, probably a crater but not sufficiently examined to be certain of this.

Total 11

These eleven craters are arranged along a line running about NE-SW for a distance of 13 miles, suggesting that they are connected with some tectonic fissure in this part of the earth's crust. My brief examination showed no sign of any structural feature following this line, but there may well be one hidden by the covering of pliocene sandstones which overlies the whole of this region.

No great difference in age.

Another point which may be noticed is that, taken as a whole, they do not show any signs of a great difference in age. Some have been more cut into along their edges than others, but these differences may be easily explained by differences in the local conditions, which would make erosion more rapid in some places than in others. It is possible that their formation may have been spread over a long period if measured by years, but it is equally possible that the whole of the eruptions may have been compressed into a few months, weeks, or even days.

Preceded by volcanic activity.

A third point to be noticed and one in which they agree with other groups of pit craters, such as those of the Eifel and Auvergne, is that they lie in a district where there are ample signs of a long period of volcanic activity having preceded their formation, though there is no sign of their origin being directly connected with any of the foci of this older volcanic activity. As elsewhere, their formation seems to have been altogether subsequent to the cessation of volcanic activity of the normal type, and subsequent also to a great modification of the surface forms of the volcanoes, and indeed to the establishment of the existing surface forms, which have hardly been modified by the formation of the pit craters.

Absence of minor cones.

A further point, which has already been referred to but may be repeated here, is the fact that the eruptions by which these pit craters were formed, seem in each case to have ceased with great abruptness after the close of the main eruption. In only one of the craters, that of Twin west of the Chindwin, is there any sign of a minor cone; here on the north side of the lake is a low ridge, of crescentic shape in plan, which is composed of volcanic ashes dipping outwards from the concave side. With this exception there is no sign of any minor cones inside any of the craters; it is of course possible, even probable, that such may have existed and be hidden under the waters of the crater lake, or buried in the débris washed down from the crater sides, but in this case they must have been of very small size, and the existence of such small cones, due to the last expirations of the eruptive action, would not materially modify the statement which has been made as to the abrupt cessation of the eruption. It is noteworthy that this absence of minor cones within the crater is a feature common to all crater lakes and pit craters, with very few exceptions.

Nature of eruptions.

It appears also, from the facts which have been detailed, that, though we must apply the name volcanic to the explosive action by which these craters were produced, it was in many ways of a very different character from what may be called normal volcanic activity, and was rather of the nature of a violent explosion of steam or vapour, unaccompanied, as has been noticed, by the great heat which is the accompaniment of volcanic activity of the normal type. This absence of heat is in keeping with the fact that the date of their formation is altogether subsequent to the cessation of normal volcanic activity, and may also explain the abrupt cessation of activity after the relief of accumulated pressure, consequent on the great explosion by which each crater was formed.

Origin of Lonar Lake.

These craters also throw some light on the vexed question of the origin of the Lonar lake. It has long been recognised that this could not have been one of the rents from which the Deccan traps were erupted, but is of a date subsequent to the cessation of their formation; and this fact, coupled with the very small bulk of the crater rim, as compared with the volume of the cavity, has led in this case, as in that of the crater lakes of the Eifel, to the hypothesis that the hollow is due to subsidence. By comparison with the pit craters of the Lower Chindwin District it is seen that the two cases agree in the long period which elapsed between the cessation of ordinary volcanic action and the formation of the pit craters; while the absence of a crater rim at all commensurate in volume with that of the cavity is accounted for by what has been seen at Leshe, where the material blown out from the pit was scattered in a thin layer over a broad expanse of country, and only to a very small extent accumulated in the immediate neighbourhood of the rent, to form a crater rim of inconsiderable volume as compared with that of the cavity of the crater pit. Moreover this rim, being situated on the very edge of the crater, is especially exposed to denudation, and has very probably been largely removed by it in the case of the Lonar pit, as it has been completely removed in the case of the Lower Chindwin craters on account of the softness of the rocks composing their sides.

Cause of the lakes.

In treating of crater lakes most text-books ascribe the presence of water to a supposed consolidation of the lake floor, by which it is rendered impermeable, and so retains water. In the Chindwin crater lakes, no such explanation is necessary; the presence of a lake is due in every case to the crater pit having been excavated to a lower level than the local level of permanent saturation. In each case there is a continual percolation of fresh water into the lake, whose level is kept down by the great evaporation which goes on in the dry climate of this region, and the villages perched on the edge of the craters derive their water-supply from shallow pits dug on the margin of the lakes.

ON THE LAVAS OF PAVAGAD HILL. BY L. LEIGH FERMOR, A.R.S.M., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 18 to 22.)

CONTENTS.

I.—INTRODUCTION.

IN the Hálol sub-division of the Panch Maháls district, Bombay Presidency, is situated the huge terraced block of horizontally-bedded lavas known as Pávágad (or Powagarh) Hill. This outlier of the Deccan Trap formation is, according to the late Dr. W. T. Blanford's map of this region,[1] some 7 miles in length from north to south by 4 miles in width. It rises like an island from the low-lying plains which extend for miles from its base towards every point of the compass. The summit of the hill is 2,720 feet above sea-level, or about 2,400 feet above the surrounding plains.

Owing, therefore, to its great height, without foot-hills or spurs of any size to lessen the abruptness of its rise, Pávágad Hill forms a conspicuous landmark visible from a distance of many miles in every direction. The imposing character of the hill is also largely due to the great height of the vertical scarps which bound the various lava flows, and thus impart to the hill its terraced appearance (see Plate 18).

As might have been anticipated, Pávágad Hill, owing both to its isolated position and its natural strength, has been used as a fortress from early times, and has in consequence been the scene of many a struggle, accompanied by several changes of ownership. In the fifteenth century, when this fort was in the possession of the Musalmáns, the now ruined city of Chámpáner situated at its base (see Plate 18) was for a time the capital of Gujarát and consequently a place of great importance.

Literature:— Dr. W. T. Blanford, (1869).

The only geological notice of this hill is contained in the late Dr. W. T. Blanford's paper entitled "On the geology of the Taptee and Lower Nerbudda valleys and some adjoining districts,"[2] and I cannot better preface my own remarks than by quoting *in extenso* a portion of Dr. Blanford's paper.

"The traps of Powagurh, unlike those to the south-east, are perfectly horizontal, and a large portion of them possess a very peculiar mineral character. The number of terraces on the hill side is far greater than usual; there are 20 in a thickness of about 500 feet below the upper flat: only a portion of these are due to the ordinary

[1] *Mem. Geol. Surv. Ind.*, VI, Part 3, Pl. 3, (1869).

[2] *Loc. cit.*, pp. 343, 344.

basaltic lava flows; the remainder consist of a peculiar light purple argillaceous rock, rare elsewhere. It has a somewhat cherty appearance, and generally contains small crystals of glassy felspar: this rock is sometimes mottled, purple and grey; it is almost always distinctly marked by planes of lamination, parallel to the stratification, and sometimes so finely so as to resemble an ordinary shale more than a volcanic rock; yet these beds occasionally appear to pass into basaltic trap, and one form of basalt, that containing crystals of glassy felspar, weathers, at the edges of blocks, into a substance closely resembling the purplish shaly rock just described.

"It is not easy to explain the formation of such beds. Frequently they have the appearance of volcanic ash, but, on the other hand, their highly laminated structure appears due to deposition in water; yet it is in places irregular, and the beds contain pumice, which could hardly be expected to occur in subaqueous formations. There is a possibility of these rocks having been flows of volcanic mud of great tenuity, or their peculiar character may, in part at least, be due to changes subsequent to their consolidation. Similar beds are very rare amongst the traps, and no other instance of their development on an equally extensive scale elsewhere has as yet been observed in Western India."

The writer's visit.

Whilst passing through the Panch Mahâls district in February 1905, I took the opportunity of ascending Pávágad Hill, but as only a single day could be devoted to the purpose it was not found possible, interesting as it would have been, to examine in detail the numerous lava flows and thus construct a section of the hill showing the nature of each flow. The general parallelism and horizontality of the flows was, however, apparent and is illustrated by Plates 18 and 20.

Several specimens were collected and a microscopical examination of them has brought out some interesting features worth recording; and I may as well say at once that the peculiar lavas, concerning the nature of which Blanford was so doubtful, and which he suggested might be volcanic mud-flows of great tenuity, are really rhyolites. It will, moreover, be well to mention here that, as will be later more fully explained, since Blanford wrote the above Mr. F. Fedden[1] has found what he designates as 'trachy-felsites' and 'quartz-felsites,' in frequent association with the basaltic Deccan Trap lavas of Káthiáwár,

[1] *Mem. Geol. Surv. Ind.*, XXI, pp. 96—99, (1885).

and that on examination I find that these trachy-felsites, etc., are rhyolites similar to those of Pávágad Hill.

II.—DESCRIPTION OF THE SPECIMENS.

The following table shows the names assigned to the various rock-specimens collected, and in addition gives their specific gravities, and the registered numbers in the Geological Survey collections of both the rock-specimens and the corresponding microscope-slides :—

	Rock-register number.	Microscope-slide number.	NAME OF ROCK.	Specific gravity, G.
No. 1	18·92	5219	Basalt	2·95
No. 2	18·93	5220	Amygdaloidal earthy basalt with scolecite.	...
No. 3	18·94	5221	Purplish-red amygdaloidal lava with heulandite.	2·71
No. 4	18·95	5222	Pitchstone with felspar and augite phenocrysts.	2·54
No. 5	18·97	5224	Rhyolite with felspar and quartz phenocrysts.	2·51
No. 6	18·96	5223	Rhyolite with felspar phenocrysts .	2·56
No. 7	18·98	5225	Rhyolite	2·51
No. 8	18·99	5226	Rhyolite	2·59
No. 9	18·100	5227	Silicified rhyolite-breccia . .	2·47
No. 10	18·101	5228	Rhyolitic ash	2·33

I propose to give in this section a short description, both macroscopic and microscopic, of each of the above rocks and then in Section III of this paper to discuss their relationships, not only to one another, but also, in the case of the rhyolites, to similar rocks found in Káthiáwár and Malání.

No. 1—18·92—5219—*Basalt.*

This was collected just before the third gate of the Mohoti Darwáza[1] and is a fine-grained, hard, compact rock of dark greenish-

[1] A detailed plan of Pávágad on the scale of 500 yards = 1 inch, showing all the fortifications, gates, etc., is given in Vol. III of the *Bombay Gazetteer*, p. 196, (1879).

grey colour with red ferruginous stains in places. M.[1]—It is seen to be a typical basalt. There are a few *labradorite* phenocrysts, but the larger portion of the rock is a fine-grained aggregate of *plagioclase* laths, *augite* and *magnetite* granules. The felspar laths are considerably larger than the granules of augite and magnetite and the structure is consequently intersertal rather than ophitic. In addition to these minerals there are also present small irregular interstitial patches of a brown or yellow-brown substance of low refractive index, polarizing in part as an aggregate of low double refraction, and in part like concentrically-layered chalcedony.

No. 2—18·93—5220—*Amygdaloidal basalt with scolecite.*

The steps leading up to the Budhiya Darwáza have been hewn out of an amygdaloidal basaltic trap noticeable on account of the large white radiate patches of *scolecite* which it contains. The rock is very fine-grained, dull dark grey in colour, and is crumbly and somewhat earthy in appearance. Besides the scolecite it contains calcite and chalcedony in amygdular infillings and is in places scoriaceous. M.—Owing to the friable character of the rock it was not easy to prepare a thin section; but the slice where thinnest shows abundant tiny felspar laths with opaque interstitial matter, which under a $\frac{1}{4}$ inch objective is seen to contain transparent grains which are probably *augite*. The structure is that of a basalt, of which this rock is probably an altered form. There are also a few somewhat altered small *plagioclase* phenocrysts. Amygdular *calcite* and *chalcedony* are also present in the slide.

No. 3—18·94.—5221—*Purplish-red amygdaloidal lava with heulandite.*

This specimen was collected from the steps just above the Makái Kothárs. It has a purplish-red matrix of earthy texture in which are set very abundant amygdules, mostly globular in shape, and usually between $\frac{1}{64}$ and $\frac{1}{8}$ inch in diameter. These amygdules are almost invariably quite solid and usually composed of *heulandite*, although a certain proportion consist of an opaque white jasper. But there are occasional geodic cavities up to $\frac{3}{8}$ inch diameter, lined with plates of heulandite. M.—The matrix consists of an opaque brown substance, traversed by small *plagioclase* laths, which contains scattered here

[1] "M" means "microscopic aspect" or "under the microscope."

and there a few aggregates of small pale yellowish augite phenocrysts. There are also scattered through the ground-mass small phenocrysts of the orange-red micaceous mineral so characteristic of the lavas of Mahábaleshwar in the Sátára district. This is the mineral described by Carter[1] under the name of 'magnesia-mica' or 'rubellan.' It is, however, probably an altered mineral and not rubellan, so that its composition remains to be determined. The *jasper* amygdules are opaque except for the actual periphery, which is of chalcedonic quartz, and for a few transparent isotropic cracks radiating from the periphery into the opaque central portions.

No. 4—18·95—5222—*Pitchstone with phenocrysts of felspar and augite.*

(Plate 21, figs. 1 and 2.)

This rock was not seen *in situ*, but was broken from a loose block found on the Mauliya, the large plateau-like area surrounding the culminating peak of Pávágad. It is a rather dull greenish-black pitchstone with a somewhat uneven fracture—best described as 'bumpy'—due perhaps to the tendency to perlitic structure which the microscope reveals. Weathering results in the production of an earthy-looking ash-grey crust. Small chips of the rock are magnetic and fuse to a white blebby glass. Scattered through the rock are rather abundant greenish glassy phenocrysts of felspar and augite. The green colour is no doubt due to the background of pitchstone showing through the glassy crystals. M.—The pale brownish glassy ground-mass is traversed by not very numerous thin intersecting cracks some of which are curved, indicating perhaps a tendency to perlitic structure. Some of the larger cracks are green, due to a deposit of viridite along them. The ground-mass appears minutely stippled throughout and under the $\frac{1}{4}$ inch objective these stipplings are seen to be due to translucent grey granules of high refractive index (? augite). Crossing the nicols shows that the pale brownish base, surrounding these granules, consists of glass containing abundant tiny laths of dimly visible *plagioclastic* felspar. The large and abundant felspar phenocrysts are frequently corroded by the ground-mass, portions of which they often include (as shown in Plate 21, fig. 2). A small proportion of these are untwinned and hence in all

[1] "Western India," p. 709, (1857).

probability *orthoclastic*; but the majority show polysynthetic twinning, and are sometimes zoned; the extinction angles referred to the albite twinning-lamellæ point to oligoclase-andesine as the species. There are also a few phenocrysts of pale yellowish-brown *augite*, sometimes twinned on the ortho-pinacoid; some of these augites have been altered in places to a bright-green substance which often shows spherulitic interference crosses; in some cases the alteration has become complete resulting in the formation of a green pseudomorph (? of *serpentine*) after augite. A few scattered grains of *magnetite* are also present in the ground-mass and in the felspar *apatite* is occasionally seen.

No. 5—18·97—5224—*Rhyolite with phenocrysts of quartz and felspar.*

(Plate 22, fig. 2.)

This was broken from a loose block near the site of No. 6 (below). It is banded, being pale greyish and soft in most bands but darkish grey and chert-like in one band inside the specimen. M.—The resemblance to some of the Maláni rhyolites collected by Mr. La Touche is very striking. Crossed nicols reveal, as in the Maláni rhyolites, a mosaic in which each individual is composed of *quartz* ophitically enclosing, in addition to various opaque granules, abundant minute felspar microlites. These at first sight appear to be micrographically intergrown with the quartz, but a close inspection shows that the felspar microlites are as a rule quite irregularly orientated. When any one of the quartz patches is in a position of extinction it is seen to be studded with abundant points of light corresponding to the felspars.

Besides a few small altered phenocrysts of *felspar* (? orthoclase) there are a few rounded phenocrysts and irregularly-shaped clear patches of quartz. These are almost invariably in optical continuity with the quartz of one of the immediately adjoining individuals of the ground-mass mosaic. One round quartz phenocryst is apparently twinned, but this is probably a strain effect. The interesting point is that each half of the 'twin' has an attached 'court' of the groundmass in optical continuity with it. Plate 22, fig. 2, shows a photomicrograph of a thin slice of this rock viewed by polarized light. The figure shows the ground-mass mosaic with a central round quartz phenocryst at the position of maximum illumination. The white-spotted zone surrounding the phenocryst on three sides has its quartz in optical continuity with the phenocryst and consequently also at the position of maximum illumination. This figure should be compared with Mr. La Touche's figure of a Maláni rhyolite (fig. 4, pl. 9, *Mem. Geol. Surv. Ind.*, XXXV). Besides a little *magnetite*, the slide also exhibits some irregular ochreous patches and some greenish pseudomorphs after *augite* (?).

No. 6—18·96—5223—*Rhyolite with felspar phenocrysts.*

This specimen was collected from an outcrop on the path leading from Chámpáner to the Atak Gate. It was, as far as could be seen, *in situ*, and hence shows that some of the lowest flows composing Pávágad hill consist of rhyolite. It is mottled dark purplish and pale lavender-grey with ferruginous stains along cracks; where purplish it is harder and cherty in aspect and where grey it is softer and more earthy. The rock contains scattered felspar phenocrysts up to ⅛ inch diameter. M.—The ground-mass appears greyish by ordinary light, with fluidal structure well marked in places. It shows abundant tiny specks which are seen under ½ and ¼ inch objectives, some to be *magnetite* (?) cubes, some orange grains of *hematite* (?)and a still larger number microlites of *felspar*. On crossing the nicols this groundmass polarizes as a mosaic similar to that of No. 5, but with smaller patches. Felspar phenocrysts are much more abundant than in the preceding rock; they are idiomorphic, either isolated or aggregated into groups, and are usually untwinned and hence probably orthoclase. *Quartz* phenocrysts are rarer, but possess the usual 'courts.' There is also a thin vein of mosaic quartz with brown dust on either side. It is, no doubt, secondary.

No. 7—18·98—5225—*Rhyolite.*

This specimen was collected from a loose block just after passing the Atak Gate at the beginning of the ascent of Pávágad Hill. It shows a dark purplish-grey dull horny matrix, throughout which are scattered abundant tiny soft buff-coloured spots. Some are circular and some more irregular in shape due to the union of two or more round ones. There are also some larger patches of similar character either angular or somewhat rounded, and sometimes as much as ½ inch in diameter.

A few rather glassy felspar phenocrysts are scattered through the rock. M.—Exhibits the usual mosaic ground-mass under crossed nicols, but on a much smaller scale than in the two preceding rocks. By ordinary light many rounded spots, sometimes isolated and sometimes congregating into twos and threes, are seen scattered through the ground-mass. There are two varieties. Some, which are but slightly darker than the ground-mass, are shown by the ¼ inch objective to be aggregations of minute crystals of a greenish mineral—perhaps *hornblende.* The ground-mass passes right through them. The others are opaque (yellowish by reflected light) with fuzzy edges. They sometimes contain small clear yellow practically isotropic patches, and at other times portions of the ground-mass. It is possible that these opaque spots, although they suggest altered spherulites, are the altered form of the clearer ones. Scattered throughout the ground-mass is an abundance of tiny granules of red *iron-ore*, which also borders the scattered grains of *magnetite.* Several phenocrysts of rather fresh *orthoclase*, one of which has been corroded by the ground-mass, and one phenocryst of fresh *oligoclase*, were seen in the slides.

No. 8—18·99—5226—*Rhyolite.*

The three preceding specimens were collected near the base of the hill. This one, on the other hand, was collected near the summit, namely, on the path leading from the top of the hill to the Nav Lákh Kóthars shown in Plate 20, fig. 2. It has a mottled appearance due to soft, lavender or ashy-grey, patches set in a purplish network of cherty-looking rock which is not scratched by a knife. There is a fair abundance of small felspar phenocrysts with accompanying altered verdigris-green granules of viridite. The weathered external crust of the rock consists of a buff-coloured substance looking exactly like some varieties of bauxite, while there are, in places in the rock, dark patches of hard compact limonite (?). M.—The mosaic of the ground-mass is much finer grained than usual and is full of minute dark specks. There are no quartz phenocrysts. The felspar phenocrysts are both *orthoclase* and *plagioclase.* The latter has extinction-angles up to 27° referred to the albite twinning-lamellæ and hence is very acid labradorite. There are also a few phenocrysts—composed of an intergrowth of *viridite*, *red* and *black iron-ores*—formed from a pre-existing *pyroxene.* The viridite shows spherulitic crosses in places and is possibly *chlorite*. Several granules of *magnetite* are also present.

No. 9—18·100—5227—*Silicified rhyolite-breccia.*

(Plate 22, fig. 2.)

This specimen was broken from a loose block on the pathway below the Súraj Gate, *i.e.*, just before reaching the Mauliya plateau. It shows a purple matrix, not scratched by a knife, in which are set abundant angular buff-coloured fragments of rhyolite. They are soft and range up to 2 inches across; when large they often contain phenocrysts of felspar. M.—Shows abundance of angular fragments of glass of grey, yellow, orange, and brown colours, usually much darker on the borders. Most pieces show signs of a cryptocrystalline structure under a high power and contain abundant minute dark specks. Some pieces show flow structures, and others enclose orthoclase phenocrysts. One large piece is evidently pumice the cavities of which have been infilled with secondary quartz. These fragments are set in a matrix of micro-crystalline quartz of varying degrees of fineness. This quartz is evidently of secondary origin and there has been a tendency for it to grow out from the surfaces of the glass fragments. *Felspar* phenocrysts are fairly abundant in this groundmass, but their boundaries have been corroded by the quartz, little veins of which often cut across the felspars. The latter are some sanidine and some plagioclase (andesine). It is evident that the original flow was a rhyolitic lava into which were showered abundant fragments of rhyolitic glass, pumice, etc. Subsequent to consolidation the matrix of the rock has been largely silicified and this silicification has so far extended to the included fragments as to fill up cavities in pumice. The question as to how much silica, if any, has been introduced from without, has not been investigated.

No. 10—18·101—5228—*Rhyolitic ash.*

This is the rock which, at least in part, accounts for the existence of the plateau known as the Mauliya. Being a soft rock, easily denuded, it has been removed much faster than the hard, and consequently resistant, underlying traps and has also facilitated the removal of the equally resistant overlying lavas which now only remain as a small island forming the summit layer of the hill shown in Plate 19 and

Plate 20, fig. 1. The specimen is a friable porous greenish-buff earthy rock, the fragmental character of which can be with difficulty discerned by the naked eye. M.—Shows fragments of *quartz*, *plagioclase*, yellow, brown and grey glass, set in a more or less opaque glassy matrix, which is probably an agglomerated mass of separate fragments of pumice and rhyolite-glass. In some places this glass shows fluidal and in others spherulitic structures.

III.—THE RELATIONSHIPS OF THE RHYOLITES.

The specimens collected having been described, we are now in a position to discuss their relationships both one to another and to some apparently similar rocks in other parts of India.

Dacitic affinities of the pitchstone and rhyolites.

Specimens Nos. 1 to 3 can be put aside at once with the remark that they are typical basic lavas of the Deccan Trap formation. The nature of No. 4 seemed at first sight doubtful. Owing to the fact that the phenocrysts are augite and felspar, mostly plagioclastic, with no quartz, I was at first inclined to regard this rock as being considerably more basic than the rhyolites. Mr. J. C. Brown, Assistant Superintendent, Geological Survey of India, kindly determined the percentage of silica which he found, in a piece having a specific gravity of 2·54, to be 69·22. This is very close to the amount he found in a piece of No. 5, having a specific gravity of 2·48, *viz.*, 69·73 per cent.

This latter rock is, of those described above under the name of rhyolite, the one with the most conspicuous quartz phenocrysts, and is consequently, in all probability, at least as acid as any of the others. Its percentage of silica, however, is very near the lower limit for this constituent in rhyolites and although, taking into consideration all the features of the acid lavas of Pávágad, it seems necessary to call them rhyolites, yet it must be noted that some of them, especially No. 8, show decided affinities to dacites: thus augite, either fresh or in altered green phenocrysts, is nearly always present; and although in each rock some of the felspar phenocrysts are orthoclase, yet the plagioclastic portion usually approaches andesine in composition, instead of albite or oligoclase the form taken by the plagioclase (when present) of typical rhyolites. Consequently the pitchstone above-mentioned may be described as a rhyolite-pitchstone approaching dacite; this latter affinity is indicated, not only by the character of the phenocrysts, but also by the abundance of minute plagioclastic felspar laths and (?) augite grains which are dimly visible (through a ⅙ inch objective) in the glassy base (see page 154). It is interesting to note that a pitchstone described by Mr. Harker[1] from the islet of Hysgeir in the Western Isles of Scotland agrees on almost every point, except the colour of the augite (green instead of brown), with the Pávágad pitchstone; Mr. Harker remarks that "it is probably to be regarded as a dacite rather than a rhyolite."

Consanguinity of the rhyolites with the basalts.

Another noticeable feature of these rhyolites is their evident petrological consanguinity with the basalts with which they are interbedded. Thus the augite phenocrysts, when present in the rhyolites, are indistinguishable in appearance from the augite of the basalts, whilst magnetite, one of the essential constituents of the basalt, is usually rather abundant in the rhyolites; the final connecting link is the basicity noticed above of the plagioclastic felspars of the rhyolites.

The Káthiáwár rhyolites (trachy-felsites of Fedden) are the same as those of Pávágád Hill.

Mr. F. Fedden, in his memoir on the geology of Káthiáwár,[2] gives a map and detailed description of the lavas of the Deccan Trap series covering such a large proportion of that peninsula. A reference to a geological map of India shows that Pávágad Hill is but an outlier which must once have been joined to the lavas of Káthiáwár on the one hand and of Khandesh (to the south of Pávágad) on the other. Fedden in his description of the lavas of the Deccan Trap series in Káthiáwár speaks of trachy-felsites, pitchstones, and obsidians; the trachy-felsites, moreover, seem to constitute quite an important member of the Deccan Trap in this area. On referring to Fedden's specimens I find that some of his trachy-felsites are both macroscopically and microscopically identical with the rhyolites of Pávágad Hill, and that the correct term to apply to at least the majority of them is 'rhyolite.'

Remarkable resemblance of the rhyolites of Pávágad and Káthiáwár to those of Maláni.

On comparing the rhyolites of Pávágad and Káthiáwár, both in hand-specimen and in thin section under the microscope, with the Maláni rhyolites of Rájputana described by Mr. T. D. La Touche,[3] I find that there is a most extraordinary resemblance, indeed at first sight even identity,

[1] Sir A. Geikie, *Quart. Jour. Geol. Soc.*, LII, p. 372, (1896).
[2] *Mem. Geol. Surv. Ind.*, XXI, pp. 73—136, (1884).
[3] *Mem. Geol. Surv. Ind.*, XXXV, pp. 78—90, (1902).

between the presumably Cretaceous rhyolites of the two former localities and the supposed Archæan Malánis. I have been able to pick out from Mr. La Touche's collection specimens which, to judge from their macroscopic aspect, might almost have been broken off the same piece of rock a certain specimens from Pávágad and Káthiáwár, except for very slight difference of tint. As good examples of this wonderful similarity the following may be given :—

(1) The rhyolite-breccia, No. 9, 19·00, from Pávágad described above, and No. 11·514 of the rock-register (micro. slide 2739) collected by Mr. La Touche about 100 feet below the top of a peak (912 feet) at Dugar (26°17′—72°43′), Jodhpur, Rájputána.

(2) A purplish rhyolite, 6·362, collected by Fedden at Pánch Taláo in Káthiáwár and the very similar rhyolite, 11·517, collected by Mr. La Touche from a knoll east of hill (937 feet) S. S. W. from Nagona (26° 8′—72° 36′), Jodhpur.

Under the microscope, however, differences may be noticed. Thus in (1) although the included fragments of lava in the Maláni specimen consist of rhyolite, yet the ground-mass has not been secondarily silicified like that of the Pávágad rock, but is instead opaque red. In the case of (2) even a close macroscopic examination is sufficient to show that, whilst all the phenocrysts of the Káthiáwár rock consist of felspar, this mineral forms but a portion of those of the Maláni rock, the remainder being quartz.

The ground-mass of the Pávágad and Maláni rhyolites.

The most remarkable feature of all, however, in the similarity between these two groups of rhyolites lies in the structure of the ground-mass as seen in thin sections.

Mr. La Touche describes the ground-mass of the Maláni rhyolites in the following words :—[1]

"In many of the specimens the ground-mass breaks up on the application of polarized light into a more or less irregular mosaic of light and dark areas (Pl. IX, figs. 4, 5), in which, when in a position of extinction, the felspar microlites appear as dim points of light. That the matrix of each of these areas consists of crystalline quartz is evident when they are in contact with the quartz phenocrysts, for it is then seen that the quartz of the phenocryst is in optical continuity with the substance filling the interstices between

[1] *Mem. Geol. Surv. Ind.*, XXXV, p. 83.

the felspar microlites. The original quartz of the phenocryst and the 'secondary' quartz of the ground-mass extinguish simultaneously, the latter forming the closed areas or 'courts' surrounding the phenocryst, already described."[1]

This description of the ground-mass applies exactly to the ground-mass of the Pávágad rhyolites as described on page 155, as also does it to some of those of Káthiáwár; whilst, when quartz phenocrysts are present, which is not always, they show the same optical continuity with the quartz of the ground-mass (Plate 22, fig. 2).

Alternative hypotheses as to the age of the Pávágad rhyolites.

Mr. La Touche, who kindly looked at my Pávágad specimens, agrees with me as to their remarkable resemblance to the Maláni rhyolites. In consequence of this similarity we are confronted with two alternative hypotheses.

(1) According to Mr. La Touche there can be no doubt that the Maláni rhyolites are Archæan in age.[2] Hence, if we admit the identity between the Maláni rhyolites and those of Pávágad (and of Káthiáwár), it is necessary to suppose that the basaltic lavas of Deccan Trap age, with which they are interbedded, have been intruded along the bedding planes of the rhyolite, in such a way as not to disturb their general horizontality; the result being a great thickness of interbedded Archæan rhyolites and Cretaceous basalts. Such a reading of the facts would be in conformity with the idea long ago put forward by Carter[3] that some of the horizontal lava sheets of the Deccan Trap are really horizontal sills intrusive in the remainder, and opposed to the usual custom of regarding the whole series as extrusive.[4]

[1] *Mem. Geol. Surv. Ind.*, XXXV, p. 80.

[2] *Ibid*, p. 27.

[3] "Western India," p. 704, (1857).

[4] Medlicott and Blanford, "Geology of India," Part I, Chapter XIII, and especially p. 325. footnote 1, (1879). Reproduced practically unchanged in the 2nd edition revised by Mr. R. D. Oldham, Chapter XI, p. 276, footnote 2, (1894). In speaking of the "physical impossibility of an immense dyke" being "injected horizontally for hundreds of miles instead of breaking through to the surface" the authors appear to have overlooked the physical possibility of horizontal dykes, *i.e.*, of sills, of smaller horizontal extension. The probability is that a considerable portion of the more crystalline basalts and dolerites of the Deccan Trap series is of the nature of sills, the more amygdaloidal rocks being the surface lava flows. This probability is very much strengthened by the demonstration by Mr. A. Harker in his memoir entitled "The Tertiary Igneous Rocks of Skye," p. 29 and Chapter XIV, (1904), that a large proportion of the basic flows of Skye consist of sills intrusive in the lavas.

(2) If, on the other hand, it be supposed that the Pávágad (and Káthiáwár) rhyolites are an integral portion of the Deccan Trap formation, then it will be necessary to admit that the two distinct groups of rhyolites, Cretaceous and Archæan, have been poured out and cooled under such conditions that they have both developed the peculiar structure of the ground-mass described above, which though apparently not uncommon in acid intrusives (quartz-porphyries and micro-pegmatites, etc.), does not seem, as far as I can discover, to have been noticed in rhyolites before Mr. La Touche described those of Maláni.

On a close comparison of the two sets of rhyolites it was found that in spite of the extraordinary similarity in structure there are slight though possibly important mineralogical differences between them. In the first place, in the Maláni rhyolites the felspar phenocrysts, although sometimes oligoclase, consist almost always of orthoclase,[1] while in those of Pávágad plagioclastic felspars are much more frequent and are often, as already noticed,[2] as basic as andesine. Secondly, although some of the Pávágad and Káthiáwár rhyolites contain free phenocrystal quartz quite as abundantly as the Maláni rocks, yet quartz phenocrysts are much more frequently absent in the former than in the latter. Thirdly, Mr La Touche[3] has noted but one example, and that doubtful, of augite in the Maláni rhyolites; while, as was noticed above, this mineral is often fairly plentiful in the Pávágad rhyolites. On a previous page the apparent consanguinity between the rhyolites and basalts of Pávágad has been noticed and hence, taking all the above facts into consideration, we can fairly accept the second of the hypotheses outlined above and conclude that the Pávágad (and Káthiáwár) rhyolites are an integral portion of the Deccan Trap series. This conclusion is supported by the negative evidence that Mr. Fedden in his detailed survey of Káthiáwár has not recorded any intrusive relations of the basalts with regard to the 'trachy-felsites' or rhyolites. My examination of Pávágad Hill was too cursory to enable me to state with certainty, although it seems probable from a glance at the horizontally-bedded structure of the hill, that there exist no sections showing the basalts intrusive with regard to the rhyolites.

[1] La Touche, *loc. cit.*, pp. 81, 82.
[2] *Supra*, pp. 155 and 157.
[3] *Loc cit.*, p. 82.

To account for the interbedding of Cretaceous rhyolites and basalts at Pávágad and in Káthiáwár we can suppose that the molten magma from which the Deccan Trap outbursts were derived had in this part of India become differentiated into two portions, an acid and a basic, and that according as the acid or the basic portion of the magma was tapped, so were the erupted lavas rhyolites or basalts.

A differentiated magma.

It has long been known that lavas of about the same age as the Deccan Trap of India, *i.e.*, uppermost Cretaceous just passing up into lowermost eocene, occur in Abyssinia, Arabia, Persia and Balúchistán. They vary in character from rocks as basic as basalts to rocks as acid as rhyolites; but rhyolites seem to be somewhat scarce, basalts and the intermediate lavas, andesites and trachytes, being of much more frequent occurrence. The lavas on the islands of the Persian Gulf, near the Straits of Hormuz, have been observed by Mr. Pilgrim to consist entirely of rhyolites, trachytes, ash-beds and tuffs, which he has called the Hormuz series and attributes to the same period as the Deccan Trap. But it is possible that the non-observance of basic rocks is due to the small thickness of rocks exposed. This almost constant association of rocks of varying composition is, no doubt, a consequence of differentiation of the magma from which they were derived. Káthiáwár and Gujarát (in which Pávágad is situated) exhibit the same association of basic and acid (or intermediate) types as the countries further west, but the uniformly basic character of the volcanic rocks over the remainder of India indicates either that the magma was more generally basic here than elsewhere, or that the more siliceous products of differentiation never found their way to the surface.[1]

Distribution and character of the magma.

With regard to the peculiar structures exhibited by these rhyolites, both Cretaceous and Archæan, Mr. La Touche,[2] in writing of the Maláni rocks, advances reasons for supposing that the evidence of the optical continuity of individuals of the quartz mosaic of the ground-mass with the quartz phenocrysts shows that this mosaic is an original feature dating from the time of consolidation of the rock, rather than the

Time of the formation of the ground-mass of the rhyolites.

[1] See also Holland, "General Report of the Geological Survey of India for the year 1905," *Rec. Geol. Surv. Ind.*, XXXIII, p. 79, (1906).
[2] *Loc. cit.*, pp. 83, 84.

result of secondary devitrification of an originally glassy magma. His reasons seem to me quite good; but it is necessary to note here a rock which may demand a slight modification of his supposition.

The evidence of a granite from Singhbhum.

Amongst the specimens that I collected last year in the Singhbhum district of Bengal is a granite[1] from Gitilpi (22°31′—85°52′) which shows a tendency to a granulitic structure in the form of *quartz de corrosion* occurring as round areas (probably cross-sections of finger-like processes) in the orthoclase felspar. This felspar has been much altered with the production of a felt of sericite scales set in secondary quartz. This latter sometimes occupies the whole of one felspar so that we have a case of quartz full of sericite pseudomorphous after orthoclase. In more than one case this secondary quartz is seen to be in optical continuity with one of the round included areas of *quartz de corrosion*. In this rock the *quartz de corrosion* can be regarded as analogous to the quartz phenocrysts of the rhyolites, while the orthoclase, changed to sericite and quartz, the latter in optical continuity with the *quartz de corrosion*, can be looked upon as the analogue of the ground-mass of the rhyolite; this ground-mass, as already noted, consisting of felspar microlites thickly scattered through a quartz mosaic. The felspar must have been altered to sericite and quartz subsequently to the crystallization of the granite, though this change may have followed immediately, due to the action of vapour or water contained in the granite; this change, then, like the alteration of the peridotite from Mysore described by Mr. Holland,[2] can be designated as 'secondary' only because of its immediately posterior relation in time to the 'primary' crystallization of the rock. At the time when this change occurred the granite was probably still sufficiently plastic to allow the molecular mobility requisite for the relatively secondary quartz to assume crystallographic continuity with the primary quartz. It seems to me that the case of this granite points to the conclusion that the ground-mass of the rhyolites may possibly have first more or less solidified into a glass or crypto-crystalline base and that it may have become subsequently devitrified, the devitrification starting at once while the rock was still hot.

[1] 18·159 and Micro. slide 5282.
[2] *Mem. Geol. Surv. Ind.*, XXXIV, pt. 1, (1901).

IV.—SUMMARY.

Pávágad Hill is a huge isolated terraced block of horizontally-bedded lavas forming an outlier of the Deccan Trap formation.

The specimens collected, a description of which is given, show that these lavas are divisible into two groups, a basic and an acid.

The basic lavas are basalts, often amygdaloidal, and typical of the Deccan Trap formation, while the acid lavas consist of various varieties of rhyolite, a very uncommon rock in the Deccan Trap series.

On examination of Mr. Fedden's Káthiáwár specimens it was found that the rocks, from the Deccan Trap area of that peninsula, which he calls trachy-felsites are really rhyolites, some of them being very similar both macroscopically and microscopically to those of Pávágad Hill.

The Archæan rhyolites of the Maláni series of Rájputána, described by Mr. La Touche, also show a remarkable similarity with those of Pávágad.

The question then arises as to whether the Pávágad rhyolites are to be correlated with the Cretaceous Deccan Trap rhyolites of Káthiáwár or with the Archæan Maláni rhyolites of Rájputána.

It is shown that the rhyolites of Pávágad exhibit a petrological consanguinity with the basaltic lavas with which they are interbedded, and that although the lavas of all three areas have an identical and very interesting ground-mass structure, yet there are certain features in which the Pávágad and Káthiáwár rhyolites differ from those of Maláni.

The chief points of difference are:—

(*a*) Quartz phenocrysts are much more frequently absent in the former than in the latter.

(*b*) The felspar phenocrysts are often plagioclastic, frequently as basic as andesine, in the Pávágad rocks, while they are almost always orthoclastic in the Malánis.

(*c*) Augite phenocrysts are of fairly frequent occurrence in the Pávágad rhyolites, and completely absent, except for one doubtful exception noticed by Mr. La Touche, in the Malánis.

The Pávágad rhyolites are hence considered to be slightly more basic in character than the Malánis and to have dacitic affinities;

moreover, they are to be regarded as the product of the same series of volcanic outbursts as the basalts with which they are interbedded, and hence Cretaceous; they are to be correlated with the rhyolites of Káthiáwár. It follows, therefore, that the magma from which these lavas were derived must have been differentiated into two portions, an acid and a basic.

Concerning the curious mosaic ground-mass (of the rhyolites of all three localities, Pávágad, Káthiáwár and Maláni), patches of which often exhibit optical continuity with included quartz phenocrysts, the case of an altered granite from Singhbhum is cited as, by analogy, hinting that the structure of the ground-mass may not be an absolutely primary feature as supposed by Mr. La Touche in the case of the Malání rhyolites; but that the ground-mass may have solidified in either the glassy or cryptocrystalline condition and that devitrification set in at once while the rock was still hot and more or less plastic.

In conclusion, I should like to suggest that an interesting problem for a future visitor to Pávágad Hill, would be to work out the succession of lava-flows with the object of constructing a complete vertical section of the 2,400 feet of rock exposed, so as to show the composition of each of the very numerous flows composing the hill. Such work would, amongst other things, lead, no doubt, to the discovery of many interesting lavas and would show whether the greater thickness of flows is acid or basic. For such a task, however, the observer would require to spend much more time than the one day I was able to devote to this scenically, historically and geologically, fascinating hill.

ON THE ASSOCIATION OF GIBBSITE WITH MANGANESE-ORE FROM TALEVADI, BELGAUM DISTRICT, AND ON GIBBSITE FROM BHEKOWLI, SATARA DISTRICT. BY L. LEIGH FERMOR, A.R.S.M., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plate 23.)

Gibbsite in Indian laterites.

THE work done during the last few years on the Indian bauxites has shown that they often possess a composition approximating to that of gibbsite[1] ($Al_2O_3.3H_2O$); the nearest approach to the theoretical composition has been found by H. Warth[2] in some cream-coloured nodules forming a bed, one foot thick, between the soil and the under-lying rocks of the Charnockite series at Kodaikanal, Palni Hills. The specimens analysed have, however, with the exception of the above, been more of the nature of rocks than pure minerals, and the gibbsite they contain is either quite amorphous, or only visible as minute glistening scales, as in some specimens recently collected by the present writer at Yeruli (18° 2′—73° 34′) in the Sátára district, Bombay Presidency.

Gibbsite from the Belgaum district.

Mr J. Malcolm Maclaren visited, during the field-season of 1904-05, the locality of Talevadi (15° 33′—74° 28′) in the Belgaum district, Bombay Presidency, for the purpose of examining the manganese-ores known to occur there. The manganese-ore takes the form of nodules of psilomelane scattered through ferruginous laterite, which shows a gradual passage downwards, in some places into quartz-schist and in others into a decomposed argillaceous schist. Associated with the manganese-ores, Mr. Maclaren found veinlets of a white crystalline mineral which he identified provisionally as gibbsite, and in some notes he sent me on the occurrence he says, "The main feature about

Association of alumina and manganese in laterite.

the deposit is the clear separation of the various oxides—iron, manganese and aluminium—and judging from the association of the two

[1] T. H. Holland, *Rec. Geol. Surv. Ind.* XXXII, pp. 177—180, (1905).
[2] *Min. Mag.*, XIII, p. 172, (1902).

last I think there were closer bonds between them than with the iron. Certainly I did not notice any gibbsite with the iron oxides."

Several examples are known of manganese-ores associated with Indian laterite, *e.g.*, in the districts of Sátára and Jabalpur; but it is a curious fact that, in spite of the bauxitic, *i.e.*, aluminous, character of much of the Indian laterite, the manganese-ores have, up to the present, been found associated with the more ferruginous rather than the more aluminous varieties of this rock.

The oxides of iron and aluminium found in laterite are usually, as one would expect from their chemical behaviour, in very intimate association. Sometimes small light-coloured aluminous segregations occur in a dark ferruginous matrix and at other times the reverse holds, according to the relative amounts of these two elements. But the association of these two oxides is often so intimate that they are probably molecularly intermingled so as to form a more or less uniform mixture. With manganese, however, no such half-way stages exist. As far as I am aware no laterite, unless containing visible manganese-ore, has yet been analysed[1] in which more than a very small percentage of manganese has been found. Manganese, when present, renders itself conspicuous by segregating into black nodules or veins which one would, without any hesitation, call manganese-ore.

Thus we see that the evidence of laterite agrees with the experience of the chemical laboratory in indicating that iron and aluminium are chemically much more closely related to each other than either is to manganese, and that the latter is more closely related to iron than to aluminium. Consequently Mr. Maclaren's discovery of gibbsite associated with manganese-oxides in preference to the neighbouring iron-oxides is surprising. Since the gibbsite both encrusts and fills in cracks and cavities in the manganese-ore it is evident that it was deposited after the latter had been formed; and it is therefore difficult to explain why it should not also have been deposited in the ferruginous laterite in which the manganese-nodules occur.

Description of the specimens.

A brief account will now be given of the specimens (J. 875) forwarded by Mr. Maclaren to the Geological Survey Laboratory. The manganese-ore with which this gibbsite is associated is very cavernous and consists partly of typical hard psilomelane, sometimes showing

[1] With the exception of what is almost a pure iron ore containing 1·54 per cent. of Mn_3O_4, from Emelia, Jabalpur district. Mallet, *Rec. Geol. Surv. Ind.*, XVI, p. 108, (1883).

finely mammillated surfaces in cavities, and partly of ore which resembles psilomelane in appearance, but is soft enough to be easily scratched with a knife with production of a brownish-black streak, and which is hence perhaps best designated 'wad.' There is also a certain proportion of pyrolusite. Coating the manganese-ore is a mammillated white layer of gibbsite averaging $\frac{1}{8}$ inch, but ranging between $\frac{1}{16}$ and $\frac{3}{16}$ inch in thickness. It has a radiate structure, the fibres or narrow plates springing out roughly at right angles to the surface of the manganese-ore. It is greyish-white in colour and semi-transparent, but shows thin bands, concentric with the mammillary surface, of slightly greater opacity and white colour. It breaks into prismatic fragments, which turn opaque white on heating, give off water, are infusible, react for aluminium with cobalt nitrate solution, and are soluble in boiling concentrated sulphuric acid. G = 2·40 and H = perhaps as high as 3. That the mineral is gibbsite, as indicated by the above tests, is proved by the following analysis made by S. Sethu Rama Rau, B.A., in the Geological Survey Laboratory:—

Moisture and combined water	34·75	per cent.
SiO_2	2·01	
Al_2O_3	63·59	
	100·35	

The silica is to be regarded as an impurity. The outer surface of the gibbsite layers sometimes has a very thin coating of brown iron oxide.

The fibrous gibbsite rests upon, or passes laterally into, a buffish-white aggregate of tiny scales which when examined under the microscope are seen to be transparent, colourless, possess angles of about 120°, and yield a biaxial figure of moderately large optic axial angle. They are hence doubtless also gibbsite. Gibbsite also lines nearly all the cavities in the manganese-ore, but is then more often crystalline occurring as an aggregate of very pale yellow-brown tabular crystals with angles of 120° and good basal cleavage. Some of these when detached and examined under the microscope are seen to be twins, the twining plane being $\perp$ *c* and probably that numbered (4) in Dana's System of Mineralogy, p. 254, 6th edition. The colouration is due to iron-staining along the cleavage planes of the otherwise colourless mineral.

Description of the plate.

Fig. 1, Plate 23, is a photomicrograph of a thin section of the encrusting gibbsite and shows well the radiate and concentric structures of these crusts. The black radiate streaks in the figure correspond to opaque white streaks in the section. The thin slice looks much more transparent than the figure suggests; in the figure the contrasts have been purposely increased so as to bring out the structure. The polarization colours vary from grey of the first order to tints as high as those of muscovite. The direction of lesser elasticity (*c*) is approximately at right angles to the length of the fibres, the elongation of which corresponds therefore to the breadth of a cleavage plate of the mineral.

Fig. 2, Plate 23, represents a section of one of the gibbsite crusts where it comes in contact with the manganese-ore, and it will be seen that, instead of the radiate fibrous structure possessed by the external portions of the crust, the gibbsite has here crystallized into small tabular crystals the cross-sections of which, owing to the perfect basal cleavage, resemble in appearance books of mica. Their idiomorphism with regard to the manganese-ore indicates, since we know that the gibbsite was formed later than the manganese-ore, that their formation has been accompanied by a certain amount of metasomatic replacement of the ore by gibbsite.

Gibbsite from the Satara district.

It will be of interest to notice here a specimen (J. 901) of gibbsite which I found lying loose on the ground near Bhekowli on the Mahábaleshwar plateau, Sátára district. It is mottled creamy-grey in colour and was at first thought to be halloysite which it resembles exactly in its porcellanous aspect. It is, however, somewhat harder than halloysite and has a specific gravity of 2·35. A quantitative analysis kindly undertaken by Mr. J. C. Brown, Assistant Superintendent, Geological Survey of India, yielded the following result:—

Moisture	0·62 per cent.
Combined water	34·51
SiO_2	0·39
Al_2O_3	64·20
	99·72

corresponding almost exactly with the theoretical composition of gibbsite. Though found loose, it seems probable that this specimen is derived from the laterite which is found close to the place where the specimen was lying.

The silica shown in the analyses of the Talevadi and Bhekowli gibbsites is doubtless an impurity; after eliminating this constituent, and, in the case of the Bhekowli analysis, the moisture, and calculating to 100 the analyses can be compared, as in the following table, with the theoretical composition of gibbsite corresponding to the formula $Al_2O_3.3H_2O$:—

	Talevadi.	Bhekowli.	Theoretical.
H_2O	35·33	34·96	34·58
Al_2O_3	64·67	65·04	65·42
	100·00	100·00	100·00

The excess of water in the Talevadi analysis is due to the fact that it includes the moisture which was not determined separately.

It is interesting to notice that in the two specimens above described we have in one case (Talevadi) the crystalline variety originally known as *hydrargillite* and in the other (Bhekowli) the amorphous form to which the term *gibbsite* is applied

THE CLASSIFICATION OF THE TERTIARY SYSTEM IN SIND WITH REFERENCE TO THE ZONAL DISTRIBUTION OF THE EOCENE ECHINOIDEA DESCRIBED BY DUNCAN AND SLADEN. BY E. VREDENBURG, A.R.S.M., A.R.C.S., *Geological Survey of India.*

I.—BLANFORD'S CLASSIFICATION OF THE TERTIARY SYSTEM IN SIND.

THE Tertiary strata of Western Sind were divided by the late Dr. W. T. Blanford into five series which were named, in ascending order, Ranikot, Khirthar, Nari, Gáj, and Manchhar.[1] Uncomformities were noticed at several places, but were regarded as local, the relations of the five principal divisions to one another being interpreted generally as one of perfect continuity, so much so that it was stated that no sharp boundary could be drawn between the various groups, the classification being founded entirely on palæontological data. This interpretation was extended to the sedimentary beds associated with volcanic rocks that underlie the Ranikot and were named after one of the leading fossils the "*Cardita Beaumonti* beds," which were consequently regarded as intermediate between Cretaceous and Tertiary. The age assigned to the Ranikot was Lower Eocene, the Khirthar was regarded as Eocene, the Nari as Upper Eocene or Oligocene to Lower Miocene, the Gáj as Miocene, the Manchhar identified with the Siwalik formation of the Sub-Himalayan region, as Upper Miocene to Pliocene.

II.—AMENDMENTS TO THE ABOVE CLASSIFICATION.

Subsequent researches in Sind and Balúchistán, and the general advance of geological science, have enabled us to define the exact age of these sub-divisions and their mutual relations more accurately than

[1] *Rec. Geol Surv. Ind.*, IX, p. 9, 1876; XI, p. 163, 1878; *Manual*, 1st ed., p. 447, 1879; *Mem. Geol. Surv. Ind.*, XVII, p. 32, 1879.

was possible in 1879. The main feature disclosed by later surveys is the great importance of the stratigraphical gaps between most of the groups. It is only in the case of the Nari and Gáj that a perfectly gradual passage can be detected in almost every instance, where the two series occur side by side, the faunistic differences being moreover far less pronounced than between the other groups. In all the other cases the gaps represent geological intervals comparable in importance to the duration of the groups which they separate. The Khirthar series has proved to be heterogeneous and includes a lower member, the Laki group, intermediate between the Ranikot and Khirthar, and unconformable to both. The failure to recognise these gaps has had the effect of spreading the duration of each group over an exaggerated geological range, and of creating the mistaken impression of the existence of passage beds between some of the terms of the geological sequence such as the supposed bridge which was thought to have been detected between Cretaceous and Tertiary. I have endeavoured to fix the age of the several divisions principally by means of a study of the fossil foraminifera. The result of this enquiry has been published in a previous number of these *Records* (Part II, pp. 79 to 95).

The "*Cardita Beaumonti* beds" must be relegated entirely to the Cretaceous, mostly, if not entirely, to the Senonian, their uppermost layers perhaps occasionally touching the Danian. The Ranikot includes two divisions, a lower one consisting mostly of fluviatile sandstones, and an upper one largely made up of limestones with marine fossils. Nummulites make their first appearance in the upper portion of the newer division, the most characteristic species being *Nummulites planulatus*. The Ranikot series probably represents the greater part of the Ypresian. There is a complete faunistic break as regards several groups of invertebrates between the Ranikot and the Laki. The characteristic nummulites of the Laki are *Nummulites atacicus* and *Assilina granulosa*. This division may be taken to represent a part of the Lower Lutetian. The Khirthar was divided by Blanford into two sections, a lower one principally arenaceous and shaly, and an upper one mostly calcareous. These divisions correspond roughly with the Middle and Upper Lutetian. In the note already alluded to, I gave the zonal distribution of the Khirthar nummulites. *Assilina exponens* and *Nummulites lævigatus* are the forms chiefly met with in the lower division, extending also into the lower part of the newer calcareous group; this passage zone may be conveniently spoken of as the "Middle Khirthar." This Middle Khirthar includes the strata with the richest nummulite fauna. Two horizons can be recognised; amongst other species, *N. gizehensis* specially characterises the lower one, while the upper one is distinguished by the presence of *N. Murchisoni*, *N. Beaumonti*, and *A. spira*, the latter extending also into higher zones. The most characteristic species of the upper zones of the Upper Khirthar is *N. complanatus*. In the Mula Pass in Balúchistán, where the sequence in the Upper Khirthar and Lower Nari is more complete than elsewhere, some beds towards the top of the Khirthar formation have been doubtfully referred to the Bartonian In Sind, the Khirthar is very incomplete as compared with the neighbouring districts of Balúchistán, and is practically restricted to the Middle Khirthar, the true Lower and Upper Khirthar being almost entirely wanting. The Nari and Gáj include all the beds rich in large lepidocyclines and may be taken to represent the bulk of the oligocene. In the Mula Pass, some beds at the base of the Nari without lepidocyclines but with reticulated nummulites may be taken to represent locally a portion of the Sannoisian, the Lower Nari generally corresponding with the Stampian, the Upper Nari with the Lower and Middle Aquitanian, the Gáj with the Upper Aquitanian. In the Mekran and in Southern Sind, the Gáj is continued conformably upwards by beds of Burdigalian age, locally reaching perhaps into Middle Miocene. The conglomerate at the base of the Manchhar contains the well-known fauna of Pikermi affinities which is referable to the Pontian.

This sequence is interrupted by several gaps which are of greater extent at certain localities than at others, but which are nowhere completely bridged over. The first one corresponding with the Montian and Thanetian separates the *Cardita Beaumonti* beds and associated volcanic rocks from the Ranikot, and occupies the same stratigraphical position as the break between Cretaceous and Tertiary observed in other countries The next gap, between the Ranikot and Laki, represents the upper part of the Ypresian. A portion of the Middle Lutetian, of various extent according to various localities, is missing between the Laki and Khirthar. A part or the whole of the Bartonian together with the lower portion of the Oligocene is missing between the Khirthar and Nari. Varying amounts of the Middle to Lower Miocene are wanting between the Gáj and Manchhar.

It is only the minimum extent of these gaps that is reckoned in the above statements. For instance, the section in the Mula Pass showing Khirthar beds higher than the zone of *N. complanatus* and Nari beds lower than the horizon of the lepidocyclines is quite exceptional. Even in this exceptional instance there is not a complete passage, but in every other locality the break is far more pronounced. This is always the case in Sind, where, except at the northernmost extremity of the Khirthar range, the greater part of the Upper Khirthar is invariably missing, and various horizons of the Nari or Gáj rest indifferently on the Khirthar or Laki. Whenever Manchhar beds occur in Sind, the newest beds that come into contact with them belong to the Upper Oligocene Gáj. The true Lower Miocene of Southern Sind and the Mekran, including the beds that I have classified as "Hingláj sandstones," (page 90 of this volume,) overlie conformably the Gáj proper, but do not come into contact with the Manchhars, these being absent from the region of outcrop of the Hingláj beds The uppermost beds of the Hingláj series are probably of Middle Miocene age (Helvetian-Tortonian or Sarmatian), but there is no indication tending to show that any of them are so late in age as the base of the Manchhars, and they cannot be regarded as marine equivalents of the Manchhars or Siwaliks as suggested in some of the publications of the Geological Survey of India.[1] A mammalian fauna of Middle Miocene age has been found in the Bugti hills of Balúchistán, but nothing is known regarding the relation of the beds containing it to the Siwaliks.

Thus the Tertiary of Balúchistán and Sind includes five totally independent series. In Balúchistán, the unconformable breaks between these divisions are often very conspicuous, but in Sind, where the degree of disturbance of the strata is slight and the structure regular, being to a large extent the result of only one period of orogenic movement, that which last affected the district and accounts for the tilting of the Siwaliks, there is usually such a perfect parallelism of stratification amongst successive beds, even when they are widely different in age, that the discontinuity of the succession has been

[1] *Manual*, 1st ed, p. 471; *Mem. Geol. Surv. Ind*, Vol. XVII, p. 64.
The so-called Mekran series supposed to be equivalent to the Gáj or newer, includes beds of the same age as the Gáj as well as newer and older ones, all belonging however to one continuous conformable series, equivalent to the Pegu system of Burma, extending in geological age from Oligocene to Middle Miocene.

overlooked. In the case of the Laki and Khirthar, the circumstances are particularly deceptive. As developed in Sind, both series consist principally of massive white limestones. These limestones outcrop as anticlinal ridges, those consisting of Khirthar beds constituting the ridges in the north-western part of the hilly tract of Western Sind, the principal ones being the Khirthar, Bhit, Badhra, Dumbar, Bidur, and Kambu ranges, while in the south-eastern part of the hilly region similar ranges consist of the Laki limestone: such is the case with the Laki, Sumbak, Surjana, and Kara ranges.[1] The flat-topped hills near Rohri consist of Khirthar limestone. The similar ones near Haidarabád consist of Laki limestone. Thus, in Sind, the two limestones usually occur in separate areas, and the overlying Nari rests either upon the Khirthar or upon the Laki, in either case with apparent conformity. Along the western slopes of the Surjana range, and at the northern extremity of the Kara range, the two limestones come into immediate contact with one another in such a way that the line of demarcation would not be detected easily in the earlier stages of a geological survey. At the northern extremity of the Laki range, at the well-known fossiliferous locality of Dharan Lak, the two limestones occur separated by some calcareous shales which Blanford interpreted as merely a local development of the Khirthar. The only place where Blanford distinctly recognised the Lower Khirthar was beyond the Sind frontier at the gorge of the Gáj river in the Khirthar range. But under the impression that the Khirthar limestone and Laki limestone were identical, Blanford concluded that the Lower Khirthar shales were still older than the limestone of the Laki range and did not realise that they are intermediate in age between the two massive limestones. Indeed, Blanford even discussed the possibility of the Lower Khirthar being a facies of the Ranikot,[2] from which we know it now to be separated by the entire thickness of the Laki, not to mention the periods represented by the unconformities and gaps between these various formations.

It is in Balúchistán that the beds now known under the name of Laki were for the first time recognised as a group distinct from the Khirthar by Griesbach who designated their most characteristic member, the massive limestone, under the name of "Alveolina

[1] For the identification of these hills, reference may be made to Blanford's Memoir on the Geology of Western Sind, (*Mem. Geol. Surv. Ind.*, Vol. XVII,) or to the maps of the Atlas of India.

[2] *Mem. Surv. Ind.*, XVII, p. 44.

Limestone."[1] The presence of the same rock in Sind was first detected by Noetling and myself in the year 1900. The group thus separated from the Khirthar was named the Laki, and has been noticed by Noetling in the *Centralblatt für Mineralogie, Geologie und Palæontologie* (1903, p. 521; 1905, pages 135, 170[2]), attention being drawn also to the presence of the Laki group in Balúchistán and in the Salt Range.

The presence of characteristic nummulites indicates that the eocene beds of Jaisalmer in Rajputana and those in the Andaman Islands belong to the Laki group, while those of Subathu in the Himalaya and those of Assam belong to the Khirthar. My colleague, Mr. Tipper, has lately examined some of the eocene collections from Burma and has found that they contain specimens both from the Laki and Khirthar series. The Laki is the coal-bearing series in Balúchistán and the Punjab.[3]

In Balúchistán, where the beds are often far more disturbed than in Sind, there are indications of orogenic movements having occurred between the periods of deposition of the several members of the Tertiary, the most pronounced periods of disturbance corresponding respectively with the uppermost limit of the Eocene, the Middle Miocene, and the Pliocene, the two latter indicating the commencement and close of the Siwalik period. Well-marked erosion unconformity has resulted, greatly facilitating the task of classifying these beds. As already mentioned, the mountains of Sind appear to owe their structure almost entirely to the last of these orogenic periods, and although there have been considerable interruptions in the sedimentation, more so than is often the case in Balúchistán, they are not revealed by any defect in the parallelism of the successive formations. The indications of erosion, such as irregularities in the

[1] *Mem. Geol. Surv. Ind.*, XVIII, p. 9, 1881. Following Blanford's suggestion with respect to the beds of the Gáj river section, Griesbach referred to the Ranikot the shales and sandstones overlying the Alveolina limestone. In the section referred to by Griesbach, that of the Bolan Pass, these beds do not belong to the Lower Khirthar, but to the "Ghazij" (Oldham), an upper member of the Laki. The classification adopted in my work on the Balúchistán desert is affected by the same error: all the rocks which I classified as Ranikot should be referred to the Laki. (*Mem. Geol. Surv. Ind.*, XXXI).

[2] The beds entered as Ghazij, in the table, p. 170, do not belong to that formation, but to the Middle Khirthar.

[3] The lignite bed once exploited at Leilan in Sind occurs in the Lower Ranikot. In Assam and Burma, the Tertiary coal appears to occur in the Pegu group and is probably oligocene.

junction bed, or the presence of conglomerates, are scanty. When observed, their importance was minimised at the time of the earlier surveys, or they were to some extent misinterpreted, such as in the case of some curious ferruginous sandstones in the neighbourhood of Kotri which mark the junction between the Ranikot and Laki, but which, not being seen in clear contact with the latter, were regarded as possibly Gáj outliers.[1]

A peculiar brecciated condition of the nummulitic limestones of Balúchistán in their lowermost beds had long been noticed, but for a long time was not taken to indicate unconformity, the opposite being even argued, and so much so as to derive support for the supposed continuous passage from Cretaceous to Tertiary.[2] Of late years I have observed innumerable instances where this breccia passes into a true conglomerate. It is always the lowermost beds of the limestones that exhibit the structure, and I have invariably found it connected with an unconformable junction. It is found at the base both of the Laki and of the Khirthar. The passage from an unconformity conglomerate upwards into a compact limestone indicates a deepening of the water in which these strata were deposited. I am inclined to think that the brecciated structure might indicate that the rock when still imperfectly indurated was situated in fairly shallow water: the depth might be sufficiently small to be still within the region of wave influence, and the action of the waves might be sometimes sufficient to detach portions of the imperfectly indurated rock. This explanation would account for the passage of the limestone breccia into one containing fragments of foreign rocks, at the same time accounting for the fact that the fragments in the calcareous portion of the breccia are not really derived boulders, but consist of a rock similar to the matrix and containing the same fossils.[3]

Mr. Holland has suggested to me that the action might have been

[1] *Mem. Geol. Surv. Ind.*, XVII, pp. 146, 147.

[2] *Mem. Geol. Surv. Ind.*, XVII, p. 98, (1879); XX, p. 45, (1883); *Rec. Geol. Surv. Ind.*, XIX, p. 203, (1886); XXIII, p. 94, (1890); XXV, p. 22, (1892); *Manual*, 2nd ed., pp. 291, 304.

[3] An explanation, not similar, but somewhat analogous, may be invoked to explain the brecciated appearance of some of the volcanic and intrusive rocks in Balúchistán and in the Himalaya. Sometimes the fragments in the breccia consist of rocks similar or closely allied to that constituting the matrix, but the breccia is apt to pass into a rock where most of or all the fragments consist of foreign rocks. Partial solidification and subsequent movement are indicated thereby, suggesting a process somewhat similar to, though not identical with, that which caused the limestone breccia.

somewhat analogous to that observed along calcareous coasts at the present day, especially when fringed by living coral reefs. The fragments detached during violent storms are heaped up by the force of the waves into a bank which becomes recemented by calcite into a solid mass. Whatever may be the true explanation of these breccias, the points to which I particularly wish to draw attention are as follows: the structure is not concretionary, but truly fragmental; the age of the breccia is not uniform as it may occur in different geological series; typical instances always accompany an unconformity; and the age of the immediately underlying rock varies widely. Thus, although it does not of itself constitute the proof of an unconformity otherwise well established on stratigraphical and palæontological grounds, yet, far from suggesting a conformable junction as interpreted by my predecessor, its presence indicates and accentuates the situation of a stratigraphical break. In offering a conclusion thus widely diverging from that of so distinguished an authority, it may be stated that I have had many opportunities to examine the question far more thoroughly than could have been done in Mr. Oldham's preliminary traverses.

The scantiness of distinct indications of erosion unconformity in Sind suggests that during the periods that intervened between the formation of the several groups, the land, though emerged, remained at a very low altitude above sea-level. The slope was not sufficient to allow of the production of deep erosion, while the scanty alluvial deposits that might have accumulated would have been rapidly removed by the waves during the next period of subsidence before a sufficient depth was reached for the deposition of the succeeding sedimentary series. In many cases we have indications to show that during these continental intervals, the rock did not receive any covering of alluvium, but remained exposed to the atmosphere, being slowly decomposed with the formation of a layer of laterite. In the absence of erosion or stratigraphical unconformities, or of basal conglomerates, these lateritic layers are the surest sign for recognising the breaks between the successive series. These lateritic bands have been noticed in Blanford's "Geology of Western Sind," but without any special reference to their true signification, though it is mentioned that one of them occurs precisely at the junction of the Ranikot and Khirthar (*i.e.*, Laki),[1] and another just below the base of the Manchhar.[2]

[1] *Mem. Geol. Surv. Ind.*, XVII, pp. 46, 144, 145, 149, 151.
[2] *Loc. cit.*, pp. 137, 141, 145.

Enough is known now of the origin of laterite to establish that these ferruginous layers are undoubted proof of continental conditions.[1]

One difficulty yet remains to be disposed of with regard to the stratigraphical relations of the Sind formations. This is the statement repeatedly made in the "Geology of Western Sind," that the passage from one group to the other is often so gradual that it is not possible to draw an exact line of demarcation. It is evident that this excludes all local instances of unconformity, or even the presence of any distinctive feature such as a band of laterite, or even a distinct petrological change. The instances thus alluded to are in the midst of continuous successions of beds, all of a similar character, usually shales or sandstones, and appear, at first sight, difficult to reconcile with the definite evidence as to breaks between the various formations. What has really happened in these cases is that the geological boundary has been misplaced, and has been drawn in the midst of one stratigraphical group instead of between two successive members. The most conspicuous instance of such an error is the boundary between the Khirthar (Laki) and the Ranikot as drawn on the geological map illustrating the Memoir on Western Sind from the neighbourhood of Bolari as far south as Tatta. The true Ranikot boundary has been overlooked, and runs much further east than indicated along the whole of this line. In the neighbourhood of Tatta there are no Ranikot beds. The boundary shown on the map runs amongst calcareous shales that belong to the Laki formation, but show a strong lithological resemblance to some of the Ranikot beds. This region was never visited by Blanford, but was surveyed by Fedden who assisted him during the geological survey of Sind. A similar explanation accounts for the supposed passage from the Gáj into the Manchhar which is said to have been observed in the Khirthar range and in the Karáchi region: only whilst in the case of the supposed Ranikot-Laki passage the boundary has been drawn too high, in the case of the supposed Gáj-Manchhar transition, the error is in the opposite direction. The supposed passage beds are principally arenaceous layers into which the calcareous beds of the Gáj gradually pass upwards. They represent the transition from the Upper Oligocene Gáj to the Lower

[1] The ferruginous layer containing the *Otoceras* fauna in the Himalaya is perhaps also laterite-stained, and perhaps it will be found that the supposed continuity between the marine formations of the Palæozoic and of the Mesozoic in India is just as illusory as the supposed bridge between Cretaceous and Tertiary has now proved to be.

Miocene beds including the Hingláj sandstones, but are not in any way connected with the true Manchhars or Siwaliks, in spite of lithological resemblances. In the case of the exposures in the Khirthar range, the Manchhar boundary has probably been overlooked, locally concealed as it might be by talus. In the Karáchi region, there are no Manchhar beds, but only uppermost Oligocene or Lower Miocene sandstones resting conformably on the Gáj. The third noticeable instance is the supposed Khirthar-Nari transition which is said to occur in the valley of the Hab river, and here the consequences of the erroneous notion as to an uninterrupted sequence in Sind have been particularly unfortunate, as this section might have been the key to much of the obscurity that has reigned for many years in our study of the Tertiary system in India. In this region, and in some of the neighbouring tracts in Balúchistán that have lately been examined by my colleague, Mr. Tipper, it is very difficult indeed to detect the exact position of the geological boundary, notwithstanding the enormous gap in time between the two successive geological formations, one being the Lower Khirthar, the other the Upper Nari. The Nari beds here have assumed the flysch facies which they exhibit over such enormous areas in Balúchistán under the name of Kojak shales, and the facies of the Lower Khirthar is almost identical. Not recognising the identity of some of these rocks with the Lower Khirthar of the Gáj river section, Blanford attempted to account for their presence in the same manner in which he tried to explain the shales of the Dharan Pass, that is, by looking upon them as a local facies of some of the Upper Khirthar limestones. By means of such a supposition, the presence of Nari beds in immediate contact did not seem anomalous, and as no conspicuous boundary was apparent amongst these frequently unfossiliferous beds, the conclusion arrived at was that of a perfectly gradual transition. These same reasons, that is, lithological similarity and scarcity of fossils, have been a constant cause of error in Balúchistán, and the extensive flysch formation known as the Kojak shales has been referred by one observer after another to the Eocene, not to mention its confusion with the Trias.[1] For several years I remained under the impression that the Kojak shales represented a facies of the Lower Khirthar. It is only during my surveys of the present year that I have finally been able to

[1] *Mem. Geol. Surv. Ind.*, XVIII, pp. 7, 32, (1881); *Rec. Geol. Surv. Ind.*, p. 95, (1887); *Manual*, 2nd ed., p. 142, (1893).

establish the oligocene age of the true Kojak shales and their identity with the oligocene flysch of Europe.

The amended classification of the pre-Quaternary beds is as follows:—

Formations.		Geological age.
Manchhar (shales and sandstones)		Pliocene to Pontian.
	Stratigraphical break . . .	Middle Miocene.
Mekran or Pegu	Hingláj (shales and sandstones) .	Mostly Burdigalian.
	Gáj (principally limestones) . .	Upper Aquitanian.
	Upper Nari (shales and sandstones)	Middle and Lower Aquitanian.
	Lower Nari (limestone) . .	Stampian.
	Stratigraphical break . . .	Bartonian.
Khirthar . .	Upper Khirthar or Spintangi limestone (poorly developed in Sind).	Mostly Upper Lutetian.
	Middle Khirthar limestone . .	Middle Lutetian.
	Lower Khirthar (shales and sandstones absent from Sind).	
	Stratigraphical break . . .	Middle Lower Lutetian.
Laki . .	Ghazij (shales and sandstones absent from Sind).	Lower Lutetian.
	Alveolina limestone . . .	
	Meting shales and limestones .	
	Stratigraphical break . . .	Lower Lutetian to Upper Ypresian.
Ranikot . .	Upper Ranikot (limestones) . .	Ypresian.
	Lower Ranikot (sandstones) . .	
	Stratigraphical break . . .	Thanetian and Montian.
	Cardita Beaumonti beds (shales, limestones, sandstones, and volcanic beds).	Mostly Maestrichtian.
	Compact limestone resting on thinner-bedded limestone with *Orbitoides.*	Campanian.

What then will be the result of these changes of interpretation upon the published geological map of Sind and upon the palæontological work accomplished by Duncan and Sladen with reference to the echinoids and corals from this region? With regard to the map, it may at once be stated that Blanford's and Fedden's surveys are admirably accurate, and that whatever alterations have now to be made affect not so much the boundaries as the interpretation of the outcrops which these boundaries circumscribe. The only boundary that needs actually shifting is that already alluded to as forming the limit of the southernmost outcrop of the Ranikot. The boundary southwards from Bolari, as represented on the published map, closely corresponds nevertheless with a geological line, being the limit between the two sub-divisions of the Laki group that occur in Sind, the Alveolina limestone above, and the Meting shales below. It is the Meting shales that have been mistaken for Ranikot beds. The beds represented as Ranikot in the neighbourhood of Tatta are also the Meting shales. The Khirthar and Laki should be coloured separately and a boundary inserted where the two come in contact. The distribution of their respective outcrops has been indicated in a previous paragraph. The separation of the Laki and Khirthar on the geological map would at once render evident the independence of the Nari and its unconformable relation to those formations. The separation of the Ranikot into an upper and lower series would make clear its unconformable relation to the Laki, as, in the Laki range, the Alveolina limestone would be represented resting directly on Lower Ranikot beds. The area shown as Manchhar to the north-east and east of Karáchi, and also the supposed Manchhar outcrop on the Mol plateau further north, should be coloured differently from the Manchhar or united with the Gáj. These outcrops consist of uppermost Oligocene or lowermost Burdigalian marine beds resting conformably on the Gáj.

III.—RE-DISTRIBUTION OF PREVIOUSLY DESCRIBED FOSSILS ACCORDING TO THE AMENDED CLASSIFICATION.

These various alterations would affect only to a trifling extent the appearance of the geological map. When, however, we come to consider the published palæontological results, the matter becomes more serious. The collections described in the *Palæontologia Indica* by Duncan and Sladen[1] were gathered with the greatest care, the specimens being always carefully labelled, often with detailed stratigraphical indications. But the failure to recognise the unconformable relations of the various stratigraphical groups caused a disregard of that excess of caution that should have been exercised whenever two different groups came into contact. As already explained, it frequently happens that beds lithologically identical but of widely different age rest upon one another with apparent perfect continuity. In such cases, the geological boundary has often been drawn a little too high or a little too low, and fossils widely differing in age have been promiscuously grouped as occurring together. This criticism has been frequently, though quite unfairly, addressed to the great work of the pioneers in the Lower Tertiary Geology of India, d'Archiac and Haime, for besides giving a separate list of all the fossils that they found associated with the reticulated nummulites, they drew attention to the fact that a certain number of fossils were unaccompanied by these foraminifera, and carefully warned their readers that it was uncertain whether this absence was accidental or whether some of the fossils might not belong to formations older or newer than the strata containing nummulites.[2] The case is very different with the Memoirs published in the *Palæontologia Indica*, for the impression is at once conveyed that a perfectly secure basis has been given to the classification, and nothing can be detected to hint at any chances of error. Occasionally the authors have noticed that a specimen differed in its mode of fossilisation from those with which it was associated, but they have readily satisfied themselves with the supposition that it had accidentally got mixed up from some other locality. This interpretation, which is apt to cast an impression of uncertainty upon the whole collection, is not the correct one. The anomalous specimens were truly collected at the localities stated, but they were derived from a different formation. It is only exceptionally that such differences in appearance betray the error: the mineral characters of the two successive formations are often exactly similar. A source of error has thus crept in that has vitiated the palæontological results throughout

[1] Sind Fossil Corals and Alcyonaria; by P. Martin Duncan, 1880. Fossil Echinoidea of Western Sind and the Coast of Belúchistán and of the Persian Gulf, from the Tertiary formations, by P. Martin Duncan and W. Percy Sladen, 1882-86.

[2] Animaux fossiles du groupe nummulitique de l'Inde, p. 359.

all the divisions of the Tertiary system in Sind. Not only do we find united under the name of Khirthar two echinoid faunæ without a single species in common and of widely divergent generic constitution, but Laki forms have crept into the Ranikot and Nari forms into the Khirthar or Laki, with the result that the distinctness of these faunas has been blurred. A far more serious confusion prevails with respect to the collections from Kachh, so much so that I have failed so far to extricate it. In Sind I have succeeded in sorting out fairly completely the fossil echinoids belonging to the three Eocene groups, the Ranikot, Laki, and Khirthar, and in some instances I have even been able to refer certain forms to special zones within these divisions. The collections which I have made from the Ranikot, Laki, and Khirthar strata include nearly all the Echinoidea described by Duncan and Sladen, and all these species can be directly referred therefore to their proper horizons. These collections do not show a single case of overlap between the three great faunas. Thus, in most cases it is now an easy matter to determine the horizon of the localities from which Blanford and Fedden obtained their collections, even when these localities have not been visited again since their survey. Some of these localities have yielded a few forms that have not re-appeared in the later collections, but when they are situated at a distance from any confusing boundary, the additional evidence which they furnish may be safely relied upon. In this way the horizon of every form has been definitely located with the exception of one species and one variety belonging to the Laki or to the Khirthar, but which cannot be referred with absolute certainty to either of these divisions, as the only specimens known came from one of the localities where the fossils are evidently mixed. They will be mentioned again when tabulating these two faunas.

In the lists tabulating the distribution of these fossils, I have entered the generic and specific names as given in Duncan and Sladen's "Fossil Echinoidea of Western Sind." Some of the generic names have been altered since the publication of this work, in some cases by Professor Duncan himself.[1] Certain species have been founded on differences of shape and size which the more extensive material now available shows to be accidental. The critical re-examination of all these questions has not been completed and their discussion would exceed the scope and object of the present paper. The names

[1] A Revision of the Genera and great Groups of the Echinoidea, by P. Martin Duncan, 1889, *Journ. Linn. Soc.* (*Zool.*), XXIII.

as originally given will suffice for the present purposes of reference and comparison.

IV.—THE ECHINOIDEA OF THE UPPER RANIKOT.

It is in the Ranikot that this zonal distribution can be most satisfactorily attempted. Most of the Ranikot collections have been obtained from localities where the different limestone bands outcrop in small scarps with low angles of dip so that one particular horizon outcrops over a considerable area, and there is not much danger of the specimens from different horizons becoming mixed. The fossils can thus readily be sorted out into zones, and it is only in the uppermost zone that a serious confusion has occurred owing to the inclusion of a number of Laki species. This confusion has resulted almost entirely from the series of specimens collected by Fedden near a locality named Petiani situated 9 miles west of Kotri (Survey number G. $\frac{280}{136}$). At this locality the Laki and Ranikot are both represented by similar white limestones in immediate contact, both richly fossiliferous. Twenty-three species were collected, of which six, that is, over one-fourth, have since proved to be characteristic Laki forms which never accompany the Ranikot echinoids in collections gathered with due care. These are: *Arachniopleurus reticulatus* D. and S.,[1] *Rhynchopygus Calderi* d'A. and H., *Rh. pygmæus* D. and S., *Hemiaster digonus* d'Arch., *Prenaster oviformis* D. and S.,[2] *Metalia Sowerbyi* d'Arch.

The erroneous inclusion of *Rhynchopygus Calderi*, *Rh. pygmæus*, *Hemiaster digonus*, and *Metalia Sowerbyi* was already suspected by Duncan and Sladen whose doubts were shared by Blanford.[3] Omitting these six species, not a single form remains in common between the Ranikot and Laki. The handsome spines from Tatta described on page 50 of Duncan and Sladen's Monograph (Plate XI, fig. 13), as included in the Ranikot collection, should also be transferred to the Laki.

[1] When describing the geology of the Balúchistán desert, I was influenced by the presence of this species in attributing the eocene beds of Koh-i-Malik Siah to the Ranikot (*Mem. Geol. Surv. Ind.*, Vol. XXXI, p. 264; *semireticula tu* is a *lapsus calami*). It is not quite certain, however, whether the Laki species may not occur in the uppermost bed of the Ranikot. The eocene beds of Koh-i-Malik Siah belong to the Laki. They contain *Nummulites atacicus*, and in their uppermost strata a small variety of *Assilina exponens*.

[2] I have found this species occurring abundantly in the Alveolina limestone in Sarawán. It has been met with by Mr. Pilgrim in beds of the same age in the Persian Gulf.

[3] The Fossil Echinoidea of Western Sind, p. 245 and foot-note.

There remain thus forty forms whose zonal distribution is as follows:—

ZONAL DISTRIBUTION OF THE RANIKOT ECHINOIDEA.

	UPPER RANIKOT.			
	Zone 1, with *Calyptrophorus* sp.	Zone 2, with *Operculina* sp.	Zone 3, with *Assilina miscella.*	Zone 4, of *Nummulites planulatus.*
Cidaris sp., D. and S., p. 25 . . .	. . .	. . .	. . .	———
„ *Verneuili* d'Arch. . . .	. . .	. . .	. . .	———
„ sp., spines, G. [illegible], D. and S., p. 5c	. . .	. . .	. . .	———
„ sp., spines, G. [illegible], D. and S., p. 50	. . .	———		
Phyllacanthus sindensis D. and S. . .	. .	. . .	. .	———
„ *Ranikoti* D. and S. . .	. . .	———		
„ sp., D. and S., p. 28 . .	. . .	. .	. . .	———
„ sp., spines, D. and S., p. 50 .	. . .			
Salenia Blanfordi D. and S. . . .	. . .	. . .	. . .	———
Cyphosoma abnormale D. and S. . .	. . .	. . .	. . .	———
„ sp., D. and S., p. 33 . .	. . .	. . .	. . .	———
„ sp., D. and S., p. 34 . .	. . .	. . .	. . .	———
Acanthechinus nodulosus D. and S. . .	. . .	———		
Dictyopleurus sicsac D. and S. . .	. .	. . .	. . .	———
„ *Haimei* D. and S. . .	. . .	———	———	
„ *d'Archiaci* D. and S. . .	. . .	. . .	———	
Progonechinus eocenicus D. and S. . .	. . .	———		
Eurypneustes grandis D. and S. . .	. . .	. . .	. . .	———
Æolopneustes de Lorioli D. and S. . .	. . .	. . .	. .	———
Conoclypeus sindensis D. and S. . .	. .	. . .	. . .	———
„ sp., D. and S., p. 52 . .	. . .	. . .	———	

	Upper Ranikot.			
	Zone 1, with *Calyptrophorus* sp.	Zone 2, with *Operculina* sp.	Zone 3, with *Assilina miscella.*	Zone 4, of *Nummulites planulatus.*
Conoclypeus declivis D. and S.	...	...	—	
Phylloclypeus sp.[1]	...	—		
Plesiolampas placenta D. and S.	...	...	—	—
" *prælonga* D. and S.	...	...	—	
" *ovalis* D. and S.	...	...	—	—
" *rostrata* D. and S.	...	...	...	—
" *polygonalis* D. and S.	...	...	...	—
Eolampas antecursor D. and S.	...	—	—	
Echinanthus enormis D. and S.	—	—	—	
Cassidulus ellipticus D. and S.	...	...	...	—
Eurhodia Morrisii, d'A. and H.	...	...	...	—
" " var., D. and S., p. 72	...	—	—	—
Paralampas pileus D. and S.	...	—		
" *minor* D. and S.	...	—		
Neocatopygus rotundus D. and S.	...	—		
Hemiaster elongatus D. and S.	...	—	—	—
Linthia indica D. and S.	...	...	—	
" sp., D. and S., p.	...	...	—	
Schizaster alveolatus D. and S.	...	...	—	

V.—THE ECHINOIDEA OF THE LAKI AND KHIRTHAR.

With regard to the Laki and Khirthar species promiscuously grouped together under the title of Khirthar in the *Palæontologia Indica*, our first task is to eliminate the oligocene species wrongly associated with them. These are the forms described by Duncan and

[1] This generic attribution is doubtful.

Sladen as *Temnechinus Rousseaui* d'Arch., *Schizaster Baluchistanensis* d'A. and H., *Moira primæva* D. and S., *Euspatangus rostratus* D. and S., *Breynia carinata* d'Arch. All these fossils were obtained from Nari beds resting directly upon Khirthar or Laki limestones. Duncan and Sladen expressed their opinion as to the probable erroneous inclusion of the forms which they referred to the genera *Temnechinus*, *Moira*, and *Breynia*. The fossil named *Breynia carinata* is very fragmentary, but the characters of the test, so far as they can be made out, seem to differ from those of the typical Gáj species, while they seem to agree with those of a form which I have observed abundantly in the Nari of Balúchistán. It differs from the typical *Breynia carinata* by the narrowness, flexuosity, and the more numerous pores of its ambulacral petals, and by the greater number of large tubercles in the paired interambulacral areas of the abactinal surface. It agrees with *Breynia carinata* and differs from the modern representatives of the genus in having pores within the internal fasciole.

With the elimination of these Nari forms, and the addition of the forms removed from Duncan and Sladen's Ranikot, the forms classified as Khirthar in the *Palæontologia Indica* sort themselves as follows, one species and one variety only being omitted, *Euspatangus cordiformis* D. and S., and *Amblypygus subrotundus* D. and S., var. *conicus*. Both were obtained only at the richly fossiliferous locality already mentioned of Dharan Lak at the northern extremity of the Laki range where the Khirthar outcrop sweeps across the Alveolina limestone and a regrettable mixture of fossils has resulted.

	LAKI.	KHIRTHAR.
Leiocidaris canaliculata D. and S.	———	
Porocidaris anomala D. and S.	———	
„ sp., spines, D. and S., p. 50[1] . .	———	
Cyphosoma macrostoma D. and S.	———	
„ *undatum* D. and S.	. . . .	———
Micropsis venustula D. and S.[2]	———	

[1] These remarkable spines probably belong to the beautiful species *Porocidaris anomala*.

[2] The Khirthar form which I referred to this species in *Mem. Geol. Surv. Ind.*, XXXI, p. 261, is closely allied but not identical. The tubercles are comparatively fewer and coarser and the dimensions are usually larger than in the case of *Micropsis venustula*. In the same list of fossils, *Assilina spira* should be read instead of *Nummulites granulosa*.

	LAKI.	KHIRTHAR.
Arachniopleurus reticulatus D. and S.	———	
Conoclypeus alveolatus D. and S.[1]	———	
" *pinguis* D. and S.	. . . .	———
" *rostratus* D. and S.	. . . .	———
" *galerus* D. and S.	. . . .	———
Echinocyamus nummuliticus D. and S.	———	
" " var. *obesus*	———	
" " var. *oviformis*	———	
" " var. *planus*	———	
" *rotundus* D. and S.	———	
Sismondia polymorpha D. and S.	. . . .	———
Amblypygus subrotundus D. and S.	———	
" *patellæformis* D. and S.	. . . .	———
" *tumidus* D. and S.	. . . .	———
" *latus* D. and S.	. . . .	———
Eolampas excentricus D. and S.	———	
Echinolampas rotunda D. and S.	———	
" *subconica* D. and S.	———	
" *obesa* D. and S.	———	
" *sindensis* d'Arch.	. . . .	———
" " var. *hemisphærica*, D. and S.	. . . .	———

[1] According to Noetling (*Centralblatt für Mineralogie, Geologie, und Palæontologie*, 1905, p. 136) this species occurs in the Khirthar in company with *Nummulites perforatus*. The latter fossil is not *N. perforatus*, but a variety of *N. gizehensis*, Sowerby's *N. obtusa*, and the attribution of the echinoid to *Conoclypeus alveolatus* is incorrect: it should be *C. galerus*, a species particularly abundant at Dharan Lak. Noetling's collection from this locality contains several specimens of this species with specimens of *Assilina spira* adhering to them clearly establishing their age as Middle Khirthar a little higher than the zone of *N. gizehensis*.

	LAKI.	KHIRTHAR.
Echinolampas angustifolia D. and S.	. . . .	——
" *nummulitica* D. and S.	——	
" *juvenilis* D. and S.	. . . .	——
" *lepadiformis* D. and S.	——	
" *æquivoca* D. and S.	. . . .	——
" sp., G. $\frac{304}{88}$, D. and S., p. 174	. . . .	——
" sp., G. $\frac{180}{106}$, D. and S., p. 176	——	
" sp., G. $\frac{180}{88}$, D. and S., p. 176[1]	——	
Echinanthus intermedius D. and S.	. . . .	——
Ilarionia sindensis D. and S.	. . . .	——
Cassidulus subinvaginatus D. and S.	. . . .	——
Rhynchopygus Calderi d'A. and H.	——	
" *pygmæus* D. and S.[2]	——	
Micraster tumidus D. and S.	. . .	——
Hemiaster apicalis D. and S.	——	
" *nobilis* D. and S.	——	
" *carinatus* D. and S.	——	
" *digonus* d'Arch.	——	
" sp., G. $\frac{180}{78}$, D. and S., p. 201	——	
" sp., G. $\frac{102}{126}$, D. and S., p. 201	——	
" cf. *apicalis*, D. and S.	——	
Brissopsis sufflatus D. and S.	——	
Metalia Sowerbyi d'Arch.	——	
" *scutiformis* d'Arch.	——	
" " var. *rotunda*, D. and S.	——	

[1] This is *Echinolampas lepadiformis*.
[2] This species is not distinct from *Rhynchopygus Calderi:* large series of specimens show every gradation between the two forms.

	LAKI.	KHIRTHAR.
Metalia depressa D. and S.[1]	——	
„ *agariciformis* D. and S.	——	
„ sp., D. and S., p. 215[2]	——	
„ „ „ 216	——	
Linthia orientalis D. and S.	. . . . .	——
Schizaster symmetricus D. and S.	——	
„ *simulans* D. and S.	. . . . .	——
„ sp., D. and S., p. 224	——	
Prenaster oviformis D. and S.	——	
Brissopatagus Sindensis D. and S. . . .	. . . . .	——
Macropneustes speciosus D. and S. . . .	——	
„ *rotundus* „	——	
Peripneustes sp., D. and S., p. 234	. . . . .	——
Euspatangus avellana d'A. and H. . . .	——	
Gen. et sp. indet., D. and S., p. 241 . . .	. . . . .	——

This table shows that there is not a single species in common between the two series and that the faunistic break between the Laki and Khirthar is just as pronounced as between the Ranikot and Laki. The distribution according to zonal sub-divisions has not been ascertained within the Laki and Khirthar with as much accuracy as in the case of the Ranikot. The number of specimens obtained from the calcareous shales is greater than that from the massive limestones. Thus, in the case of the Laki, there are more specimens from the Meting shales and the junction bed between them and the overlying Alveolina limestone than from the Alveolina limestone itself. The Khirthar forms are almost entirely from the calcareous shales of the Middle Khirthar, principally from the zone characterised by

[1] Probably identical with *Metalia Sowerbyi.*
[2] A crushed and weathered specimen of *Metalia Sowerbyi.*

Nummulites gizehensis and the immediately overlying portion of the zone of *N. Murchisoni*.

With regard to the Laki division, although the detail of the smaller zones has not been worked out, a general idea can be obtained of the distribution of the echinoids with respect to the two main sub-divisions represented in Sind, the Meting beds and the overlying Alveolina limestone. The collections that I have made from various horizons contain most of the forms belonging to the Laki that have been described by Duncan and Sladen. The faunistic difference between the Meting beds and the overlying Alveolina limestone is sufficiently distinct to fix the horizon of the few remaining forms by means of the species associated with them in Blanford's and Fedden's collections. The collections that I obtained from the Meting beds are more complete than those from the Alveolina limestone, and contain every form of the lower sub-stage, except the evidently very rare *Echinocyamus rotundus* D. and S., which nevertheless seems to belong to that horizon, and the rather uncertain species *Metalia agariciformis* D. and S., which certainly does. In the following lists the forms which I have not met with myself are distinguished with an asterisk. The genera *Eolampas*, *Rhynchopygus*, *Prenaster*, and the species *Echinolampas lepadiformis* D. and S., *Hemiaster carinatus* D. and S., *H. digonus* d'Arch., *Brissopsis sufflatus* D. and S., *Metalia Sowerbyi* d'Arch., **M. agariciformis* D. and S., are, in the present state of our knowledge, restricted to the lower sub-division. The genera *Micropsis*, *Amblypygus*, *Macropneustes*, *Euspatangus*, and the species **Leiocidaris canaliculata* D. and S., **Cyphosoma macrostoma* D. and S., **Conoclypeus alveolatus* D. and S., **Echinolampas subconica* D. and S., **E. obesa* D. and S., **E. rotunda* D. and S., **E. nummulitica* D. and S., *Hemiaster nobilis* D. and S., **H. apicalis* D. and S., *Metalia scutiformis* d'Arch., characterise the Alveolina limestone. *Porocidaris anomala* D. and S., *Arachniopleurus reticulatus* D. and S., *Echinocyamus nummuliticus* D. and S. and its numerous varieties, *Schizaster symmetricus* D. and S., are common to both sub-divisions. In the beds situated at the junction of the two sub-divisions, there is a certain amount of overlap of these two faunas. They differ from one another very much in the same degree as the faunas of the Nari and Gáj. It will be noticed that the genus *Eolampas* restricted to the lower sub-stage exists also in the underlying Ranikot, while the genera *Micropsis*, *Amblypygus*, and *Euspatangus*, characterising the upper sub-stage, extend upwards into the overlying Khirthar.

VI.—STRATIGRAPHIC DISTRIBUTION OF THE GENERA.

The relations of the three faunas are best shown by means of their generic constitution. It has already been mentioned that some of Duncan and Sladen's species are not really distinct, at the same time several new undescribed forms occur in the later collections; but as the re-examination of all the material at present available is not yet complete, and as it will not affect the main features of the generic distribution, I have, in the following list, left the figures as derived from a tabulation of the species in the monograph, omitting only the forms whose exact horizon cannot be determined.

	NUMBER OF SPECIES AND VARIETIES IN		
	Ranikot.	Laki.	Khirthar.
Cidaris	2	...	...
Phyllacanthus	3	...	...
Leiocidaris	...	1	...
Porocidaris	...	1	...
Salenia	1	...	...
Cyphosoma	3	1	1
Micropsis	...	1	...
Acanthechinus	1	...	...
Dictyopleurus	3	...	...
Arachniopleurus	...	1	...
Progonechinus	1	...	...
Eurypneustes	1	...	...
Æolopneustes	1	...	...
Conoclypeus	3	1	3
Echinocyamus	...	5	...
Sismondia	...	...	1

	Number of species and varieties in		
	Ranikot.	Laki.	Khirthar.
Amblypygus	...	1	3
Plesiolampas	5	...	...
Eolampas	1	1	...
Echinolampas	...	7	6
Echinanthus	1	...	1
Ilarionia	...	...	1
Cassidulus	1	...	1
Rhynchopygus	...	2	..
Eurhodia	2	...	...
Paralampas	2	...	...
Neocatopygus	1	...	...
Micraster	...	...	1
Hemiaster	1	7	...
Brissopsis	...	1	...
Metalia	...	7	...
Linthia	2	...	1
Schizaster	1	2	1
Prenaster	...	1	...
Brissopatagus	...	...	1
Macropneustes	...	2	...
Peripneustes	...	...	1
Euspatangus	...	1	...
Genus indet	...	...	1

Out of these thirty-nine genera, six extend from the Ranikot up to the Khirthar: these are *Cyphosoma, Conoclypeus, Echinanthus,* *Cassidulus, Linthia, Schizaster*. The decrease in the proportion of Regular Echinoidea which was noticed by Duncan and Sladen when passing from the Ranikot to the Khirthar fauna becomes much more remarkable when the Laki is separated from the true Khirthar. The Ranikot contains nine genera of Regular Echinoids and the Laki five, the only genus common to the two formations being *Cyphosoma*, and this is also the only genus of the Regulares so far described from the Khirthar. No doubt more extensive collections will reveal the presence of other forms, but the alteration in the proportion between the two great groups of Echinoids is well established, and the Laki seems to correspond to the period of transition during which one group was being superseded by the other. The remarkably isolated facies of the Ranikot fauna becomes all the more apparent by the removal of some specialised Cassidulids and Spatangoids, such as *Rhynchopygus, Prenaster, Metalia*. The genus *Salenia* and a number of curious Regular Echinoids—*Acanthechinus, Dictyopleurus, Progonechinus, Eurypneustes, Æolopneustes,* the irregular genera *Plesiolampas, Eurhodia, Paralampas, Neocatopygus*—are the forms that chiefly lend a peculiar and somewhat archaic note to the fauna With the exception of the few genera of wide range already mentioned as extending into the Khirthar, the generic connection with the Laki is very small, the only conspicuous link being furnished by the peculiar genus *Eolampas*.

Apart from the widely occurring genera already alluded to, the principal connection between the Laki and Khirthar is through the genera *Amblypygus* and *Echinolampas*. One species of *Amblypygus* has been described from the Alveolina limestone, the genus acquiring further diversity in the Khirthar. *Echinolampas* is well represented in both formations. The most characteristic genera of the Laki are *Arachniopleurus, Echinocyamus, Rhynchopygus, Hemiaster, Metalia, Prenaster, Macropneustes*. Those more particularly characterising the Khirthar are *Sismondia, Ilarionia, Peripneustes*.

I am not sufficiently acquainted with the echinoid faunas of other countries to institute detailed comparisons, but it is hoped that the above information may be of interest to geologists in attempting to correlate the Eocene formations of India with those of other districts.

I would nevertheless draw attention to two considerations of nomenclature which are suggested by the foregoing study. When considering the pronounced faunistic difference between the Laki and

Khirthar one cannot help being struck by a certain sense of disproportion with respect to the importance given to the Lutetian relatively to the other divisions of the Tertiary. No doubt the Laki and Khirthar both correspond to strata elsewhere classified as Lutetian, but in other countries these strata have been grouped together in consequence of the same oversight that accounts for the disproportionate extent of the Khirthar as originally defined, that is, the failure to recognise that a stratigraphical gap separates two distinct formations. It would be convenient if an additional divisional or at least sub-divisional name were inserted for the beds corresponding with the Laki group and characterised by *Nummulites atacicus* and *Assilina granulosa.* There is no doubt that this intercalary horizon is present in many countries.

Another feature worthy of attention is the close connection of the Nari and Gáj and the continuous passage between the latter and the Lower Miocene, as opposed to the conspicuous stratigraphical and faunistic break between the Khirthar and Nari. This is also a feature that is not peculiar to India, but is noticeable in every country where these particular horizons of the Tertiary system have been closely studied. It seems, therefore, that in the case of a two-fold division of the Tertiary such as that advocated by geologists using the terms Eogene and Neogene, the Oligocene should be grouped with the Miocene and not with the Eocene. The older Tertiary should consist of the Eocene alone, the remainder of the system forming the newer Tertiary. It is at the base and not at the summit of the Oligocene that we should seek the dawn of the modern world.

VII.—ADDITIONAL NOTE CONCERNING THE TERTIARY ECHINOIDEA FROM KACHH.

A fine series of Tertiary Echinoids from Kachh, including 44 species, has been described by Duncan and Sladen in the *Palæontologia Indica* (Ser. XIV, Vol. I, part 4, 1883). They include representatives of all the horizons occurring in Sind with the exception of the Ranikot. This rich series is unfortunately almost useless for purposes of correlation, the specimens being confused far more seriously than in the case of the Sind collection. Not only are there numerous instances of forms from widely different horizons having been grouped together, but a widespread cause of confusion exists in the grouping of strata containing reticulated nummulites together with the Eocene, while at other localities, where beds situated perhaps on exactly the same horizon happened to show only lepidocyclines, they have been regarded as belonging to a different series. Thus the Nari series has been severed into two portions, one of which has been incorporated into the Eocene. One of the most serious consequences of this error has been the inclusion of a large Clypeaster, *C. apertus* D. and S., as a member of the Eocene fauna. The actinal surface of the type is covered with specimens of *Nummulites intermedius* clearly establishing its oligocene age.

It is only specimens that happen to have foraminifera attached to them, or forms identical with species observed at definite horizons in Sind or Balúchistán, whose age can be ascertained, and these only serve to emphasize the confusion prevailing throughout the collection.

It is interesting to notice that the conical Echinolampads *E. alta* and *E. Feddeni*, or some closely allied species, occur in Balúchistán in Khirthar beds slightly higher than the strata with *Nummulites gizehensis* that have yielded the majority of the Khirthar forms from Sind, this zonal occurrence being apparently in agreement with that of allied species in Egypt.

RECORDS

OF

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THE JAIPUR AND NAZIRA COAL-FIELDS, UPPER ASSAM. BY R. R. SIMPSON, B.Sc., *late Mining Specialist, Geological Survey of India.* (With Plates 24—29.)

INTRODUCTION.

THE chief coal consumers of Upper Assam are the two railway companies whose lines traverse the area, the steamer companies plying on the Brahmaputra river, and the owners of the numerous tea-gardens of that portion of the province. Until the present time their demands have been met from a single group of collieries in the Makum coal-field. The owners of these collieries, after contending with exceptional natural difficulties requiring the expenditure of very large sums of money, have at length entered upon the enjoyment of their hard-earned monopoly. Their strategic position, however, has recently been affected by the completion of the hill-section of the Assam-Bengal Railway and the extension of the lines of that railway into Upper Assam.

Seeing that for nearly one hundred miles the new line runs parallel to and within a dozen miles of the coal-fields of the Naga Hills, it is but natural that the Railway Company is considering the advisability of opening up mines of its own for the service of the railway. It was chiefly with the object of deciding upon the most favourable locality in which to start a colliery that the recent exploration was undertaken.

The present rate at which coal is supplied to the railway is Rs. 7-4 per ton at Tinsukia junction, the northern terminus of the line. For the supply of tea-gardens there is a general rate of Rs. 15-8-0 per ton independent of the distance of a garden from the collieries. The only competitor against Assam coal is the fuel from the Bengal coal-fields, but the latter at the present rates cannot penetrate beyond Goalundo on the river, or Badarpur at the southern side of the hill-section on the railway.

The coal-fields, the economic features of which are dealt with in this report, are situated along the outer slopes of the Naga Hills on the south-eastern edge of the great alluvial plain through which flow the numerous rivers which combine to form the Brahmaputra. A small portion of the coal deposits is contained within British territory, but the bulk of the coal lies in semi-independent country just beyond the borders of the Lakhimpur and Sibsagar districts.

The ground is covered by virgin forest with a dense thorny undergrowth presenting the maximum of difficulty to penetration. Practically the only way of moving through such country is to follow the numerous streams, and it is fortunate that, as a rule, good sections of the rocks are exposed in their beds.

As might be expected, the topographical maps are very poor, and for a large portion of the area the only maps available are the same as were used by Mallet during his geological examination of the country in 1874-76.

GEOLOGY.

Although numerous observers have recorded notes on the subject, we are principally indebted for our knowledge of the geology of the area to Mr. F. R. Mallèt,[1] Geological Survey of India, who thoroughly examined the coal-fields during the seasons 1874—76. During the present examination no new facts have transpired which are not reconcilable with Mallet's interpretation of the general geological structure of the ground.

Except for recent deposits, such as the alluvium of the plains, there are but three distinct formations found within the area. In geological sequence these are :—

Tipam sandstone series	Upper Tertiary.
Coal measure series	Middle Tertiary.
Disang series . . .	

[1] *Mem. G. S. I.*, XII, Pt. 2 (1876).

The Tipam rocks are essentially massive sandstones of a grey colour often tinged with green. They are much false-bedded, and weather into grey or brown rounded masses. Their most distinguishing feature is the presence in them of numerous fragments of silicified or, occasionally, carbonized wood.

The coal measures are made up of alternations of thin-bedded shales and sandstones with carbonaceous shales and coal seams. Springs of oil are commonly associated with these rocks.

The Disang series is made up of fine-grained, usually thin-bedded sandstones and splintery, grey shales. Their geological age is doubtful, but they are apparently older than the coal measures.

The whole of these rocks have been ridged up into a series of parallel anticlines and synclines by the dynamic movements which elevated the ranges forming the south-eastern boundary of the plain of the Brahmaputra. Faulting on a large scale, and also inversion, has accompanied these movements. The subsequent denudation which has taken place has planed down the rocks, and left the coal-measures as narrow bands of high-dipping rocks partially concealed by the alluvium formed by their own degradation and that of the neighbouring formations. The general direction of dip is south-east, or towards the axis of the range.

DESCRIPTION OF COAL OUTCROPS IN THE JAIPUR COAL-FIELD.

Dekhajoli tea-garden.

In a stream forming the north-east boundary of the Dekhajoli tea-garden a bar of hard, bright coal, about 3 feet thick, crosses the stream, dipping S. 18° E. at 54°.

About 100 yards below and close to the boundary of the alluvium a cutting exposed the following section, dipping S. 15° E. at 49° :—

	Ft.	Ins.
Bands of **coal** and carbonaceous clay	3	0
Coal (sample No. 1)	5	6
Clay	0	8
Coal	0	4
Coal with two clay bands, each about 1" thick . .	1	6
Clay	0	3
Coal	1	6

The coal is very soft. This seam is in the same line of strike as that outcropping higher up ; so that, despite their different physical characteristics, the outcrops may be of one and the same bed.

At a point three-quarters of a mile to the south-west and close to the Dekhajoli tea-factory a seam of coal has been quarried in several places on the hill-side. No good section is now exposed. About seven years ago some 250 tons (7,000 maunds) of this coal are said to have been extracted. Its quality was considered inferior owing to the inclusion of bands of dirt in the section. In a stream about 700 yards further down the range the following section was exposed in a cutting made by Mr. E. Pinches, the manager of the garden :—

		Ft.	Ins.
Surface soil, etc.		5	0
Bands of coal and clay, dipping almost vertically		4	0
Coal	conforming to the general dip of the surrounding rocks.	0	10
Clay		0	3
Coal		1	1
Clay		0	8
Coal		0	10

The coal is of excellent physical quality and gave great satisfaction under the boiler in the factory. The outcrop can be traced for about 50 yards up-stream, the dip being to S. 15° E. at 45°. The outcrops described by Mallet (pp. 47-49) as occurring about 1½ miles from Tipam were not found, but better seams were discovered in two streams one mile east-north-east of the village.

The highest seam is only a foot or two in thickness, whilst about 80 feet down stream a promising outcrop, when cut through in a pit a few yards away, was found to consist of bands of hard, bright coal interbanded with clay. The total thickness is about 4 feet 6 inches, but owing to the included clay the seam is probably useless.

Ten yards beyond, a third outcrop occurs, and twenty yards below still another seam. A cutting on this last revealed the section given below:—

	Ft.	Ins.
Coal	0	6
Carbonaceous clay	0	6
Coal	3	0
Carbonaceous clay	0	8
Grey clay	2	8
Coal	1	3
Grey clay	1	0
Coal	3	3
Clay	0	4
Coal	0	4

The dip is to S. 30° E. at 60°. The coal is bright and consists of both hard and soft bands. What are probably the same seams are again exposed in a stream some 400 feet further north. A cutting on the higher of the two outcrops found gave—

	Ft.	Ins.
Coal	0	8
Carbonaceous shale	0	5
Hard, bright **coal** (sample No. 2)	4	11
Carbonaceous shale	1	4

Dip S. 25° E. at 55°.

Dihing River.

A few fragments of coal were found in a stream flowing from Daohál Hill, at a point about half a mile to S. 60° E. of Tipam. Coal is said to have been worked hereabouts, and I was shown the site of a reputed quarry. As there was a doubt as to the identification of the spot no excavating was done.

No indication of coal is to be seen in the river, but ancient quarries mark the outcrop of a seam for a distance of about 200 feet from the bank. Medlicott described the seam as being 17 feet thick, of which 10 feet was good coal. Mallet (p. 50) found four bands of coal, aggregating 5′ 4″, in a total thickness of 8′ 4″ of coal and shale.

All the quarries are now completely choked and overgrown. One of them was cleared out, and the following section exhibited:—

	Ft.	Ins.
Surface, etc.	5	0
Coaly clay	1	0
Black clay	0	6
Coal of fair quality	3	6
Black clay	1	0
Grey shale	3	0

Dip S. 40° E. at 50°.

Streams two miles south of Jaipur.

A coal seam of fair quality outcrops in a stream close to the Hukanjuri path and about two miles south a little east of Jaipur. A cutting disclosed the following section, dipping S. 85° E. at 40°:—

	Ft.	Ins.
Coal	0	10
Clay	0	8
Coal with two bands of clay 4″ and 2″ thick, respectively (sample No. 3 is from the coal 3′ 9″ thick, lying between the dirt bands)	7	10

	Ft.	Ins.
Clay	2	6
Coal	2	0

The continuation of this seam was found in a stream nearly a quarter of a mile to the north, where the following section was exposed by excavation:—

	Ft.	Ins.
Coal	3	9
Clay with strings of coal	2	6
Coal	2	6

Neighbourhood of Hapjan tea-garden.

In the same stream outcrops were found of several higher seams from 12 to 15 inches thick. Hereabouts both the coal and the adjacent rocks are strongly saturated with petroleum. The average dip is to N. 80° E. at 70°. Rather more than a mile south-west of these outcrops coal is exposed in a stream marked on the map as flowing by Manraja village, but which now runs past Taratuli. Excavation disclosed the following:—

	Ft.	Ins.
Coal with bands of clay 4", 6", and 6" thick, respectively (sample No. 4)	9	2
Clay	1	3
Coal	0	11

About ten yards beyond coal is again seen, and 70 yards further up-stream two thin seams outcrop. The general dip hereabouts is E. at 70°.

In another stream about half a mile north of the Hapjan factory the following section was measured:—

	Ft.	Ins.
Coal	2	9
Shales, clays, etc.	17	0
Coal including a 5" band of clay	2	11
Shales, clays, etc.	44	0
Coal	2	0

On the edge of the Hapjan tea-garden, and within a couple of hundred yards of the factory, a seam of coal is being quarried by the proprietor of the garden. The total thickness of the bed is 4′ 3″, and it includes bands of clay 2″ and 6″ thick, respectively. Dip S. 70° E. at 45°.

In a small tributary of the Hapjan (stream), within 100 yards of the garden, the section given below was exposed by excavation :—

	Ft.	Ins.
Coal including 1" of clay	1	3
Shales . . . about	40	0
Coal	1	0
Clay	1	8
Coal	2	5

Dip S. 60° E. at 60°.

Desam stream, etc.

Plentiful indications of petroleum are to be found in a stream about three-quarters of a mile south of the factory, but no coal was seen. Two small coal seams outcrop in a stream about one-third of a mile north of the Desam stream, the thickest is 1′ 5″ in thickness and includes 2 inches of clay. Dip N. 70° W. at 56°.

In the Desam the highest outcrop of coal exceeds 5 feet in thickness, including 6 inches of clay. On the opposite side of the stream this outcrop appears to be much impoverished, but the section is not well exposed.

Streams north of the Disang River.

About 100 yards down stream a seam, measuring 2 feet 5 inches, consists of bands of coal and clay. Dip S. 55° E. at 39°. Coal is again seen in a stream (No. 3) about a mile north of the Disang. The positions, thickness, dip, etc., of these seams and of those found in streams for a distance of three and a half miles south-west of the Disang are shown on the large scale sketch-map, Plate 25.[1] In the text the seams are given in their natural order from highest to lowest.

Stream No. 3—

		Ft.	Ins.
No. 1—**Coal** with a 4" band of shale		2	0
No. 2	**Coal** and carbonaceous shale	1	6
	Coal	2	3
No. 3—**Coal**		0	10
No. 4—**Coal** of which the upper half is of good quality		1	9
No. 5	Carbonaceous shale	0	3
	Coal	0	10

[1] This map is from a survey made with compass and tape. In the case of a few of the streams in which the outcrops are unimportant, distance and direction were estimated only.

Stream No. 3—(*Continuation of section*).

		Ft.	Ins.
No. 6	Coal . . . . at least	3	0
	Shale	8	0
	Coal	3	0
	Coal of poorer quality	0	6

Stream No. 2—

		Ft.	Ins.
No. 1	Poor coal	1	0
	Shale with a band of coal 3" thick	2	4
	Coal	1	7
	Shale	2	9
	Coal	2	0
No. 2—Coal	. . . .	2	0
No. 3—Coal	. . . .	1	0

Stream No. 3—

		Ft.	Ins.
No. 1	Coal with 3" band of shale	1	6
	Carbonaceous shale	0	3
No. 2—Coal	(same seam as (1))	2	0
No. 3—Coal	including bands of clay, 3", 10", and 3" thick, respectively	5	0
No. 4—Coal	with an inch of clay (same seam as (1) and (2))	2	5
No. 5—Coal	(possibly the same as (3))	1	10
No. 6—Coal	. . . .	1	6
No. 7	Coal (sample No. 5) exceeding	4	0
	Poor coal	0	6
	Shale	3	6
	Coal of dull appearance, the lower portion saturated with petroleum (sample No. 6)	15	0
No. 8—Coal	. . . .	1	0
No. 9—Coal	(same as (8))	2	0
No. 10—Coal	. . . .	1	0

There is considerable evidence of disturbance of the rocks seen in this stream, and the higher seams dip in the reverse direction to the general dip of the measures. Oil manifestations are pronounced.

Disang River.

Between the last-mentioned stream and the Disang River the measures are possibly faulted, the strike of the rocks bending through an angle of 70°. Inversion is also to be seen in the Disang section.

The following seams of coal were exposed by excavation :—

		Ft.	Ins.
No. 1—Mallet's first seam consists of a number of bands of **coal** included in a considerable thickness of shale. The thickest **coal** bands are 2 feet and 7 inches thick, respectively. The seam is unworkable.			
No. 2—Carbonaceous shale with a band of **coal** 6 inches thick		2	4
No. 3—**Coal** (sample No. 11). This is Mallet's second seam		5	2
No. 4	**Coal**	1	4
	Clay from 5"—12" thick	0	8
	Coal	1	7
	Carbonaceous shale	1	0
No. 5	**Coal**	2	4
	Clay	1	3
	Coal	2	0
	Clay	0	10
	Coal and clay bands	5	0

The rocks are much disturbed at this point and the dip is reversed. One hundred yards from the river bank the same seam is seen in its natural position, the section being :—

		Ft.	Ins.
No. 6	**Coal** (sample No. 12)	3	11
	Shale	1	4
	Coal	2	4
	Coal (sample No. 13)	4	10
	Shale	0	8
	Carbonaceous shale	1	1
	Coal including a band of shale 4" thick. This is Mallet's No. 3 seam	2	7
No. 7—**Coal** apparently dipping vertically.		5	0

Both above and below this seam carbonaceous shales are found containing bands of **coal** about one foot thick.

On the opposite (north-east) bank of the river, and on the same line of strike as seams Nos. 6 and 7, an old quarry was re-opened, and the following section exposed :—

		Ft.	Ins.
Coal (sample No. 8)		8	0
Clay		0	7
Coal (sample No. 9)		4	0
Clay		0	4
Coal		2	0
Inferior **coal**		1	6
Shale		4	0
Coal including 1" of clay (sample No. 7)	about	5	0

		Ft.	Ins.
No. 8	Coal (sample No. 15), Mallet's No. 4 seam	12	0
	Inferior coal	1	0

The seam is slightly faulted, the thickness of the coal at the bottom of the cutting being increased to 15 feet.

		Ft.	Ins.
No. 9	Carbonaceous shale	0	11
	Coal	2	3
	Shale from 3"—8" (sample No. 14 from the coal bands)	0	6
	Coal from 1' 0"—1' 6"	1	3
	Carbonaceous shale	0	3

This is Mallet's No. 5 seam. It must lie only a few feet below the 12 feet seam (No. 8).

On the opposite (north-east) bank of the river, and about 50 yards below the line of strike of seams Nos. 8 and 9, the following was exposed in a trench:—

		Ft.	Ins.
No. 10	Inferior coal	1	0
	Coal	2	3
	Clay including 2" of coal, from 10"—16"	1	1
	Coal (sample No. 10) from 4'—4' 6"	4	3

Streams south of the Disang River.[1]

The first stream is met with about 500 yards from the river. In its bed between points 700 and 1,000 feet, respectively, from the Raj Garh, the following seams outcrop:—

		Ft.	Ins.	
No. 1	Coal with 2" of clay	2	0	
	Shale	1	6	
	Coal	0	6	
No. 2	Coal	0	6	
	Clay	0	8	
	Coal	4	0	Dip S. 25° E. at 50°.
No. 3	Coal	3	8	
	Clay	0	3	
	Coal	4	0	

Within 75 yards of the Raj Garh, and just on the edge of the alluvium, a coal seam exceeding four feet in thickness outcrops. It is overlaid by carbonaceous shale two feet in thickness.

[1] I must express my thanks to Mr. L. D. Horne, District Locomotive Superintendent, Assam-Bengal Railway, for his valuable assistance in opening up the outcrops in this neighbourhood. Mr. R. K. Coxe, Assistant Engineer, Assam-Bengal Railway, did much of the preliminary work in the Nazira field, and I was thus enabled to complete my examination in a much shorter time than would otherwise have been required.

In the next stream, some 700 feet beyond, are found :—

		Ft.	Ins.	
No. 1	Coal	3	0	
	Shale and carbonaceous shale	3	0	
	Coal	1	6	
No. 2	Coal	1	10	
	Clay	0	5	
	Coal	1	5	Dip S. 30° E. at 35'
	Clay	0	8	
	Coal	3	5	
No. 3	Coal	2	4	
	Shale	3	0	
	Coal	3	0	
	Shale	0	9	
	Coal	4	6	

Stream No. 3 is nearly 1,000 feet beyond, and crosses the Raj Garh close to the Nim Ali, a pathway leading through old Borhat (deserted village) to the main road. In its banks and within a section measuring about 150 feet outcrops of coal are as follows :—

	Ft.	Ins.	
No. 1—Coal with 2" of clay	3	6	
No. 2 { Coal and clay	1	0	
No. 2 { Coal	1	0	Dip S.-E. at 63°.
No. 3—Coal	7	0	
No. 4—Coal with 12" of clayey coal and 2" of clay	4	6	

Streams Nos. 4 and 5 are, respectively, 600 and 1,000 feet further south-west. Some of the outcrops exposed have been quarried during recent years for use on the Namrup tea-garden. The following are the complete sections as exposed by excavation :—

No. 4 stream (right fork)—

	Ft.	Ins.	
No. 1—Bands of coal 4", 4", 8", and 1' 6" thick	1	6	Dip 50° to S. 40° E.
No. 2—Coal	0	10	
No. 3—Coal	1	0	
Carbonaceous shale and shale (sample No. 15)	2	8	Dip S. 50° E. at 56°.
Carbonaceous shale	1	0	
Shale	1	0	
Coal (sample No. 16)	2	0	
No. 4—Coal	1	6	
No. 5—Coal	0	6	
Shale and carbonaceous shale	1	10	

	Ft.	Ins.
No. 5—**Coal** (sample No. 17)	1	9
Shale with 3" of coal	1	2½
Coal (sample No. 17)	0	11
Shale	2	0
Coal (sample No. 17)	3	6

Quarries were formerly worked on seams Nos. 6 and 7; they were not re-opened during the present explorations.

No. 4 stream (left fork)—

	Ft.	Ins.	
No. 1—**Coal** with 2" band of coaly clay (sample No. 20)	4	2	Dip S. 25° E. at 40°.
No. 2—Bands of **coal** and clay	3	5	
No. 3—**Coal**	0	5	
Shale	1	0	
Coal (sample No. 19)	2	0	
Shale	1	3	
Coal (sample No. 19)	1	4	
Shale	2	6	
Coal (sample No. 19)	2	8	
No. 4—**Coal** (sample No. 18)	3	6	Dip S. 22° E. at 60°.
Shale	2	9	
Coal with 2" shale (sample No. 18)	4	0	

Stream No. 5—

	Ft.	Ins.
No. 1—**Coal**	3	0
Shale	4	0
Coal	2	4
No. 2—**Coal**	0	10
Shale	1	6
Coal	2	6
Shale	5	0
Coal	1	4
No. 3—Shales and unseen, containing bands of **coal** 10" and 18" thick, respectively	18	4
Coal	1	0
Shale	1	4
Coal	4	4

Stream No. 6 is about 750 feet beyond No. 5 stream; the coal-seams exposed are:—

	Ft.	Ins.
No. 1—**Coal** and clay bands	2	0
No. 2—**Coal**	1	4

	Ft.	Ins.
No. 3—**Coal**	4	3
Clay	1	4
Coal, coaly clay and clay	3	0
Clay	2	6
Coal	3	0
No. 4—**Coal**	4	6

In stream No. 7 three seams two feet thick and two thinner seams only were found.

Stream No. 8 is some 1,600 feet south-west of No. 6 stream. The following coal outcrops were excavated :—

	Ft.	Ins.	
No. 1—Carbonaceous shale	1	2	Dip S. 10° E. at 42°.
Coal	1	2	
No. 2—**Coal**	2	4	
No. 3—**Coal** . . . exceeds	3	0	

In stream No. 9 the dip of the rocks varies from S. 35°—45° E. at 35°—38°. The thicknesses of coal found are :—

	Ft.	Ins.
No. 1—**Coal**	2	0
Shale	1	4
Coal	1	6
No. 2—**Coal**	1	8
Carbonaceous shale and shale	6	0
Coal	1	0
Shale with a little **coal**	4	1
Coal	2	4

By reason of swampy or debris-covered ground no seams are exposed in the next three streams crossing the path.

In stream No. 13 the following coal-seams are found dipping S. at 45°—65° :—

	Ft.	Ins.
No. 1—**Coal** and carbonaceous shale	2	0
Shale	2	0
Coal	0	6
No. 2—**Coal** and clay bands	2	6
No. 3—Carbonaceons shale	1	0
Coal with 3″ band of pyritous shale	2	3
Carbonaceous shale	1	6
No. 4—**Coal**	1	0
No. 5—**Coal**	1	4

Stream No. 14 exposes several seams as follows:—

	Ft. Ins.		Ft. Ins.
No. 1—**Coal**	1 4	to	2 1
No. 2—**Coal**	1 0	to	2 0
No. 3—**Coal**			3 11
Carbonaceous shale			1 6
No. 4—**Coal**			10 0

Except in the case of No. 3 seam, which dips regularly to S. 30° E. at 50°, the rocks are much disturbed and even contorted.

The ten feet seam shown in the above section outcrops again in stream No. 15, 750 feet beyond; the thicknesses of this and other seams are:—

	Ft. Ins.		Ft. Ins.	
No. 1—**Coal**	2 4			
No. 2—**Coal** much disturbed	3 0	and	1 4	
No. 3—**Coal** (sample No. 21)	12 0			Dip S. 23° E. at 65°.

In the stream which flows through Diopani (east) village only one seam was found; the dip is S. 5° E. at 53°, the section being:—

	Ft. Ins.
Coal	0 8
Carbonaceous shale and shale	2 6
Coal	1 1

The next stream also, some 700 feet beyond, yields only one outcrop. The thickness of this seam is 3½ feet, including a three-inch band of hard shale; the dip is east at about 30°.

Some 500 feet beyond, and in a stream joining that last mentioned just above the Raj Garh three seams appear, the respective thicknesses of which are one, one, and two feet.

Thin seams only are to be found in a stream 1,500 feet further on; the thicknesses of coal measured were 2′, 1′ 8″, 3′ including 1′ of shale, 2′, 2′, and 1′ 8″, respectively. Dip S. 40° E. at 56°.

Not more than 500 feet beyond, the following coal seams are exposed in a stream bed:—

	Ft. Ins.
No. 1—**Coal** (sample No. 22)	3 4
No. 2—**Coal** (sample No. 23)	3′ 0″ to 3 6
Coal with three half-inch bands of clay	1 0
No. 3—**Coal**	3 6
Coal with clay bands	1 3

		Ft.	Ins.
No. 4—**Coal**	. . . .	0	4
Clay	. . . .	0	9
Coal	. . . .	3	5

Between Tirukia and Dablugaon.

In the eastern fork of the large stream which flows a little east of Diopani (west) village an 18-inch coal seam dips south-east at 45°. In the western fork seams were found of 12 and 21 inches in thickness, respectively.

In a small stream about quarter of a mile south-west of the large stream flowing through Tirukia the section given below was found dipping S. 55° E. at 50°:—

		Ft.	Ins.
Coal	. . . .	2	0
Shale	. . . .	1	6
Coal	. . . .	3	0
Shale	. . . .	1	0
Coal	. . . . exceeds	3	0

In the south fork of the same stream, several seams outcrop, the most important being 5 and 10 feet (sample No. 24), respectively, in thickness. The five feet seam is not completely exposed, but the coal is somewhat clayey in appearance. The neighbourhood in which are the villages of Diopani and Tirukia is known as Boruarchali, and it was hereabouts that Mallet found the seams mentioned on page 56 of his report.

In a small stream more than half a mile north-east of the stream flowing through Halua the following seams are exposed within a vertical section of about 200 feet:—

		Ft.	Ins.	
No. 1—**Coal** with a 10" band of clay	. . . .	4	1	
No. 2—**Coal**	. . . .	0	6	
No. 3—**Coal** and carbonaceous shale	. . . .	1	2	
No. 4—**Coal** and carbonaceous shale	. . . .	1	2	Dip S. E. at 45°.
Coal	. . . .	1	4	
No. 5—Carbonaceous shale and **coal**	. . . .	1	6	
No. 6—**Coal**	. . . .	0	6	

In another stream some hundreds of set to the west a coal-seam 5′ 9″ thick outcrops (sample No. 25).

In yet another stream some 200 feet beyond are found :—

	Ft.	Ins.
No. 1—**Coal** with a little carbonaceous shale . . .	1	3
No. 2—**Coal**	2	3
Carbonaceous shale	0	9

Close to and in a western fork of the same stream are :—

	Ft.	Ins.
No. 1—Three bands of **coal** in carbonaceous shale . .	3	6
No. 2—**Coal** with a 4" band of clay	2	1

In the Halua stream the dip of the rocks is to S. 50° E. at 62°, the thickness of coal being 3, 1, 2, and 1 feet respectively, whilst the shales in the neighbourhood are frequently carbonaceous.

No coal is to be found until near Dablugaon, some 2½ miles along the foot of the range. Not a trace can be seen in the Dablu stream, but in small water-courses to the east seams 16" and 6' 8" (with 3" and 10" bands of clay) thick were measured. Dip S. 60° E. at 52°. Beyond this point the coal measures are practically obscured by alluvium, but at a place known as Gajua Ting, some 3½ miles further south-west, Mallet found a seam of coal 6' 1" thick including 6 inches of shale.

Saffrai and Mattrapur tea-gardens.

The continuation of what is possibly the same belt of rocks crops up in the low range of hills flanking the Doodar Ali road between the Taukak and Saffrai Rivers. On Mallet's map these are erroneously marked as Tipam sandstones. The best exposures are on the Saffrai tea-garden where coal has been quarried on a small scale during recent years. At the time of my visit most of the excavations had collapsed and no work had been done for some time The following outcrops were measured :—

	Ft.	Ins.
No. 1—**Coal** . . . . exceeding	4	6
No. 2—Inferior **coal**	1	0
Coal with bands of shale ½" and 3" thick, respectively	3	5
No. 3—**Coal**	6	6

Dip S. 18°—30° E. at 52°—72°.

West of the Saffrai on the Mattrapur tea-garden a seam of coal was formerly worked which is said to contain about 18 inches of good coal. The dip of the rocks is steep, and the workings have collapsed, covering up the outcrop.

Inner belt of coal measures south of Kanugaon.

South of the Kanubari tea-garden, and about two miles into the hills, the existence of an inner belt of coal measures was discovered. The precise locality is on a left-bank tributary of the Tichak river and 4½ miles to S. 25° E. of Kanugaon. It must be close to the southern boundary fault, which is probably marked a little too far to the north on Mallet's map. The rocks dip S. E. at 83° and they are apparently inverted, seeing that they overlie massive sandstones of Tipam type. The thickness of the coal seams is as follows :—

	Ft.	Ins.
No. 1—Coal	2	0
No. 2—Coal . . . . . . about	23	0
No. 3—Coal	2	9
No. 4—Coal	1	9
Shale	1	9
Coal	3	0

Circumstances prevented me from following up this discovery, and I am not able to say anything regarding the lateral extension of the outcrop.

DESCRIPTION OF COAL OUTCROPS IN THE NAZIRA FIELD.

Tiru Valley.

Numerous outcrops of coal were found in the Chota Tiru, a considerable right-bank tributary of the Tiru stream. They are situated some three miles north-east of the deserted village of Chingan. Their relative position to one another is shown on the sketch map, Plate 26, whilst the thicknesses and dips are as follows :—

	Ft.	Ins.	
No. 1—Coal . . . exceeds	5	6	Dip S. 80° E. at 50°.

Several thin bands of coal underlie this outcrop.

	Ft.	Ins.	
No. 2—Coal	1	6	
Carbonaceous shale and shale	2	8	Dip E. at 72°.
Coal	3	6	
No. 3—Coal	3	9	Dip S. 60° E. at 30°
No. 4—Coal	3	9	Dip S. 35° E. at 30°.

These may all be outcrops of the same seam.

	Ft.	Ins.	
No. 5—Coal	1	3	
Carbonaceous shale and coal		3	Dip S. E. at 63°.

In a small tributary close by is found—

	Ft.	Ins.	
No. 6—**Coal**	1	8	Dip S. 35° W. at 12°.

Further down the main stream comes—

	Ft.	Ins.	
No. 7—**Coal**	4	6	Dip N. 20° W. at 60°.
No. 8—Crushed and contorted **coal** about	4	0	Strike N. 55° E.
No. 9—**Coal**	1	0	
No. 10—Three bands of **coal** 8″, 4″, and 4″, respectively .	1	4	Dip S. 35° E at 84°.

In a water-course near by these bands appear as seams 1′ and 2′ thick.

	Ft.	Ins.	
No. 12—**Coal**	1	0	
Shale	0	9	
Coal	1	4	Dip S. 65° E. at 45°.
Shale	1	6	
Coal, very irregular . .	1	3	
No. 13—**Coal**	1	6	Dip S. E. at 85°.
No. 14—**Coal**, lenticular . .	1′ 9″ to 4′ 6″		Dip S. 75° E. at 75°.
No. 15—Bands of **coal** and shale .	3	0	
No. 16—**Coal**	2	0	Dip S. 10° E. at 80°.
No. 17—**Coal** . . exceeds	5	0	
Shale	1	6	Dip N. 35° E. at 60°—70°.
Coal	2	6	
No. 18—**Coal** with 6″ of shale .	2′ 0″ to 4′ 0″		Dip S. 5° E. at 85°.
No. 19—**Coal**	1	5	Dip S. 38° E. at 80°.

Nearly 200 feet below the last mentioned outcrop a left-bank tributary joins the stream, and in it the following outcrops were measured:—

	Ft.	Ins.	
No. 1—**Coal**	2	0	
No. 2—**Coal** with 8″ band of carbonaceous shale . . .	3	8	
No. 3—**Coal** bands 18″, 18″, and 12″ thick in a total thickness of 9 feet of strata . .			Dip S. 53° E. at 90°.
No. 4—**Coal** and carbonaceous shale bands	4	0	Dip S. 75° E. at 70°.
No. 5—**Coal**	1	0	Dip S. 63° E.
No. 6—**Coal**	1	0	
Coal and carbonaceous shale	1	0	

Less than one hundred feet further down the main stream another left-bank tributary enters. In its bed the exposures are :—

	Ft.	Ins.	
No. 1—**Coal**	2	0	
No. 2—**Coal** and shale . . .	1	6	
No. 3—**Coal**	1	6	Dip 90°.
No. 4—**Coal**	1	3	Dip S. 50° E. at 70°.
No. 5—**Coal** and carbonaceous shale	1	0	
No. 6—**Coal**	0	9	Dip S. E. at 90°.
No. 7—Carbonaceous shale and **coal**	4	0	Dip S. 30° E. at 60°.
No. 8—**Coal** upper part rather shaly	2	8	Dip S. E. at 55°.
No. 9—**Coal** with 6" of shale and carbonaceous shale .	3	0	Dip S. E. at 30°.
No. 10—**Coal** with 6" of carbonaceous shale . . .	3	0	Dip N. W. at 85°.
No. 11—Irregular faulted seam containing about 2' 0" of coal	2	0	Dip S. 20° E. at 80°.

The elevation is very little above that of the alluvial plains.

In the streams at the head of the Tiru Válley careful and detailed search was made for the outcrops mentioned by Mallet on page 64. Every stream of importance was traced to its source, but not even fragments of coal were found. Excellent sections of the rocks are exposed.

Bor Valley.

The outcrops of importance occurring in the Bor and the numerous other streams falling into the Dikhu River are shown on the sketch map, Plate 27.[1]

In the tributary flowing from a point just north of Kongan village, the following outcrops of coal-seams were discovered :—

	Ft.	Ins.	
No. 1—**Coal**	2	0	
No. 2—**Coal** (sample No. 29) . .	7	6	Dip S. 70° E. at 25°.

The outcrops in the next tributary on the east are :—

	Ft.	Ins.
No. 1—**Coal**	0	5
Sandstone	0	10

[1] The topography of this map is based on an old survey made for the Assam Co. It was added to by Mr. J. D. Lowther in 1901, and considerable additions were also sketched in by myself, partly by enlargement from the Survey of India map on a scale of 2 miles = 1 inch. I am indebted to Mr. V. Woods, Acting Agent, Assam-Bengal Railway, for a copy of Mr. Lowther's map, and to him and to Mr. R. Farquharson, General Manager of the Assam Co., for kind assistance in other ways.

	Ft.	Ins.	
No. 1—**Coal**	0	8	Dip N. 80° E. at 25°.
Sandstone	0	9	
Coal (sample No. 28) . .	4	3	
Coal and shale bands. . .	1	0	

The upper coal bands thin out and disappear within 10 feet:—

	Ft.	Ins.	
No. 2—**Coal**	2	0	
No. 3—**Coal**	1	0	
No. 4—Carbonaceous shale with three or four coal bands from 3″—12″ thick.			
No. 5—Poor **coal**	0	6	
Coal with a 3″ clay-band . .	4	3	
Poor **coal** and clay	0	8	
Coal	0	5	
No. 6—**Coal**	1	0	
No. 7—**Coal**	2	0	Dip N. 70° E. at 30°.
Shale	3	0	
Coal	2	0	

In the next tributary to the north the coal outcrops are:—

	Ft.	Ins.	
No. 1—**Coal**	1	3	
Shale and coal bands . . .	1	3	Dip N. 20° E at 30°.
Coal (sample No. 27) exceeds .	7	0	

Within a few feet of the point where this section was measured a fault with a throw of two or three feet can be seen.

	Ft.	Ins.
No. 2—**Coal**	3	6

In addition coal bands of 6″, 10″, 10″, 4″, and 18″ thickness, respectively, were found.

In the next tributary on the west the following occur:—

	Ft.	Ins.	
No. 1—Bands of good and inferior **coal** .	2	0	
Shale	0	5	Dip N. 15° E. at 33°.
Coal	1	0	
No. 2—Carbonaceous shale . . .	1	0	
Coal	4	2	
Poor **coal**	0	10	
Shale and carbonaceous shale .	2	6	
Coal	1	0	
Shales with **coal** bands from .	1″to 6″		thick, respectively.

	Ft.	Ins.	
No. 3—**Coal**	0	10	
Carbonaceous shale and shale .	2	0	
Coal	0	7	
Shale	1	0	Dip N. 20°E. at 35°.
Coal	1	5	
Carbonaceous shale . . .	1	6	

About 2,500 feet west of these last-mentioned outcrops an extensive landslip exposes a fine section of the coal-measure rocks thus:—

	Ft.	Ins.	
Sandstone . . . . exceeds	100	0	
Coal	2	3	
Carbonaceous shale and thin **coal** bands .	24	0	
Shale	18	0	
Carbonaceous shale with thin **coal** bands and containing near the top a seam 18" thick	25	0	
Shales	50	0	
Sandstones	50	0	
Slightly carbonaceous shale	3	0	
Coal with dirt band 2½". thick (sample No. 26)	7	10½	Dip N. 40°E. at 32°.
Shales seen about	40	0	
Apparently massive sandstones, but inaccessible	300	0	
Coal with 14" band of carbonaceous shale .	4	1	Dip. N. 65°E. at 29°.
Shales with carbonaceous shale, and bands of **coal** 10" and 14" thick, respectively .	9	9	

At a point some 70 yards west of the 7′ 11″ seam detailed in the last section the same seam is 8′ 3″ in thickness, and is free from dirt.

Still 140 yards further west the thickness of the same seam is:—

	Ft.	Ins.	
Shaly **coal**	0	3	Dip N. 35° E. at 35°.
Coal with 2" band of dirt . . .	5	6	

Between the two latter points Mallet measured the thickness of coal as 6′ 5″.

In the Apung or Apak stream a highly inclined and much disturbed coal-seam can be traced at intervals in the bed of the river for about 100 yards. Four cuttings were made throughout this distance. In the first three the thickness of coal was, respectively, 7 feet, 9 feet, and exceeding 4 feet 6 inches; the dip being S. 55°–70° E. at 50°–85°. In the fourth and lowest cutting the following section was exposed:—

	Ft.	Ins.
Coal	9	0
Carbonaceous shales	0	10
Coal	1	1
Sandstone thinning from 2' to 1" in a depth of 3'. .	1	0
Coal, not so good	3	6
Carbonaceous shale	0	6
Coal with a few bands of carbonaceous shale . .	7	0

The seam is much contorted, and the dip varies from N. 47° W. at 84° at one end of the section to S. 55° E. at 85° at the opposite end. It was the appearance of this section which gave rise to the opinion expressed by Mr. J. D. Lowther[1] that there is here an outcrop of a coal seam 22½ feet in thickness. Such an opinion, however, is erroneous, for the section shows the seam doubled on itself, the true thickness being about 8 or 9 feet. At a point 30 feet towards the dip of the seam as exposed in the second cutting another seam is exposed, its section being:—

	Ft.	Ins.
Coal	2	6
Shale	2	8
Inferior coal	1	6

In a left bank tributary, known as the Assam Jan or stream, which enters the Bor a little above the Apung Jan, the continuation of the outcrop of the highly inclined seam gave the following sections:—

	Ft.	Ins.	The same seam 20 feet away:—	Ft.	Ins.
Coal . .	1	9	Coal . .	3	0
Shale . .	2	9	Shale . .	1	0
Coal . .	3	6	Coal . .	0	6
			Shale . .	0	6
			Coal . .	3	0

Dip. S. 55° E. at 61°.

About 15 feet below this seam comes an irregular seam of poor coal about 18″ thick.

The same belt of disturbed rocks is met with in the next left-bank tributary about a quarter of a mile to the west. The following thicknesses were measured:—

	Ft.	Ins.	
Coal with a 9" band of shale	3	6	
Shale and carbonaceous shale . .	2	0	Dip N. 38° W. at 84°.
Coal, the upper portion rather inferior .	2	10	

[1] A British mining engineer who reported on the Assam Co.'s coal concession in 1901.

About 100 feet below, a seam of coal three feet thick, including clay bands 3″ and 6″ thick, respectively, dips S. 38° E. at 75°.

Close to the path leading to the Wakting Jan outcrops, and about three-eighths of a mile south-west of the last mentioned cuttings, the same seam again outcrops with a thickness of 7 feet, and dips to S. 65° E. at 45°.

Within 10 yards of the path to Kongan, and at an elevation of 1,880 feet, the section given below was measured :—

Wakting stream.

	Ft.	Ins.	
Carbonaceous shale	1	2	
Coal	1	4	
Shale and carbonaceous shale . .	1	0	Dip S. 47° E. at 25°.
Coal	3	0	
Shale	1	6	
Coal	1	3	

On the path itself close by, and for some considerable distance down the slope of the hill, many outcrops of coal from a few inches to 2 feet in thickness were discovered. As a rule the coal is somewhat inferior. In the right fork of the Wakting the following section was exposed :—

		Ft.	Ins.	
Carbonaceous shale and coal bands .		7	0	
Shales	about	40	0	
Coal (sample No. 30)		12	0	
Shales, etc.	about	20	0	Dip N. 20° E. at 20°.
Coal and shale		3	0	
Shales, etc.	about	10	0	
Coal with 4″ of shales		2	6	

Some 50 yards down stream comes a worthless seam of coal and carbonaceous shale about 5 feet thick, dipping N. 10° W. at 35°.

Some 50 yards still further down is the locality of the 25 feet (?) seam mentioned by Mallet on p. 67 of his report. Owing to workings carried on since his visit nothing is now visible at the outcrop. Cuttings were therefore made in abandoned quarries high up on the left bank. In the highest of these the seam is 11 feet thick, pips S. 35° E. at 45°, is overlain by soft sandstone, and underlain by gray shales. In the lower quarry about 50 feet away the thickness of coal is 13 feet, whilst above the coal come alternations of shale and carbonaceous shales with thin bands of coal. The strike of the seam is approximately north-east to south-west and the dip is indefinite.

On the opposite bank, and about one hundred feet from the stream a long trench was sunk at the head of an old quarry. At the north-west end of the trench the following section was exposed:—

	Ft.	Ins.	
Inferior coal	1	0	
Shale	9	0	Dip N. 38° W. at 50°—80°.
Coal . . . . . exceeds	7	0	

Beyond this section an old gallery was met with. This was completely choked up with clay and there was a large flow of water from workings higher up. A depth of 21 feet was reached and coal had just been touched when a spell of wet weather set in, and it was found impossible to keep the excavation open. From the evidence afforded by the left bank cuttings, however, I think it is fairly proved that the true thickness of the seam is about 12 feet, and that contortion accounts for the great thickness recorded by Mallet and later by Lowther. Still further down stream thin seams of coal and carbonaceous shale are to be seen at many points.

In a water-course about 400 feet north-west of the outcrop of the high-dipping 12 feet seam a vertical and contorted seam of coal, 12 feet thick, but too much mixed with carbonaceous shale to be workable, is exposed. In another water-course about 50 yards east a little south of the outcrop of the gently-dipping 12 feet seam mentioned above, the following section is found:—

	Ft.	Ins.	
Coal	0	8	
Shale and carbonaceous shale . .	0	10	
Coal with a 3" band of dirt . . .	2	11	Dip N. 13° E. at 25°.
Shale	0	9	
Coal	1	6	
Carbonaceous shale	0	4	

Below this come about 20 feet of shales, carbonaceous shales and coal.

In the left branch of the right fork of the Wakting 11 feet of coal is exposed, but in a cutting about 20 yards to north-west the complete thickness was found to be 13 feet (sample No. 31) and the dip N. 30° E. at 17°. Further down stream we find :—

		Ft.	Ins.	
Coal	Sample No. 32	2	0	Dip N. 35° E. at 29°.
Shale		0	6	
Inferior coal		1	6	
Carbonaceous shale with bands of coal.		19	0	

The sections of the coal seams found outcropping in the left fork of the Wakting are as follows :—

	Ft.	Ins.	
No 1—Contorted bands of soft coal and shale	4	0	Dip from E. at 20° to N. 10° W. at 65°.
No. 2—Coal (sample No. 34)	5	0	
Soft black dirt	1	0	
Coal	0	7	Dip N. 15° E. at 32°.
Carbonaceous shale with thin coal bands exceeds	6	0	
No. 3—Coal (sample No. 33)	7	0	Dip S. 78° E. at 31°.
No. 4—Coal	7	6	

This last seam is apparently faulted, the amount of throw being about 30 feet.

High up in the right fork of the Telpung stream a seam of fair coal, 6′ thick (sample No. 35), is found dipping S. 50° E. at 54°. Several other seams from one to two feet thick are to be found thereabouts. In a water-course about 100 yards to the south-west two seams of poor coal, respectively 4 and 5 feet thick, dip S. 45° E. at 45°.

Telpung stream.

In the left fork of the same stream numerous outcrops of coal seams from 3″ to 15″ thick occur. One seam measures 3 feet, including a 4-inch shale band, whilst another some distance below is 4½ feet in thickness (sample No. 36), and dips to N. 80° E. at 20°. Just above the junction with the right fork come a two-feet seam including 8 inches of shale, and a three-feet seam with one foot of shale in the middle, dip S. 55° E. at 80° to 90°.

At about the same horizon, but in the right fork, a bed of coal 30 inches thick is overlaid and underlaid by thicknesses of 6 inches of carbonaceous shale. Dip N. 55° W. at 80°. Between this and the Dikhu numerous thin bands of coal and coaly shales are to be found.

Dikhu right bank.

In the first right-bank tributary entering the Dikhu above Telpung, and at an elevation of 615 feet above the level of the river, an 18-inch seam of coal dips S. 60° E. at 35°. Some considerable distance further down the following section occurs:—

	Ft.	Ins.	
Coal with a 15" band of carbonaceous shale	4	2	
Shale and carbonaceous shale . .	13	0	Dip S. 60° E. at 41°.
Coal with irregular bands of shale aggregating about 3 inches	2	6	

Still further down there is an 18" seam, followed by coal and carbonaceous shale bands aggregating 30 inches. About 100 feet below comes Mallet's four feet seam (pp. 25 and 69 of his Memoir), the continuation of the outcrop of which was found high up on the right bank, about 100 yards away. The two sections of this seam are:—

In the stream :—	Ft.	Ins.	Right bank :—	Ft.	Ins.
Coal . .	0	9			
Shale . .	0	5	**Coal** (sample No. 37)	4	3
Coal . . .	3	0			
Coal and carbonaceous shale . .	1	0	Dip S. 60°—65° E. at 21°—25°.		

On the hill-side about 100 yards to the south-west the same seam again outcrops with the section given below:—

	Ft.	Ins.	
Carbonaceous shale	0	10	
Coal	2	8	Dip S. 60° E. at 35°.
Carbonaceous shale	0	4	

In the second stream above Telpung, and perhaps 200 yards beyond the path to Kongan, we find:—

	Ft.	Ins.	
Coal	1	10	
Shale	2	8	Dip N. 80° E. at 36°.
Coal	0	10	

A little below the path quite a number of thin seams outcrop, the chief thicknesses being:—

	Ft.	Ins.	
No. 1—**Coal**	1	6	
No. 2—**Coal** with 9" band of shale .	2	9	Dip S. 60° E. at 40°.
No. 3—**Coal**, shale and carbonaceous shale	4	0	
Coal	1	8	

Some 80 yards beyond this stream, and within 120 feet of the river, there is an old quarry which was being worked about the time of Mallet's examination. Time did not permit of my clearing the excavation, but according to Mallet (p. 25) the section is:—

	Ft.	Ins.	
Coal	0	9	
Shale	0	5	
Coal	3	0	Dip S. 60° E. at 59°.
Coal with carbonaceous shale bands .	1	0	

Higher up on the hill-side, and to the east, seams about 14 inches and 2 feet thick, respectively, are to be seen at several points.

In a stream a little beyond, at a point about 100 feet from the river, a seam of coal 30 inches thick was found. The dip is to S. 35° E. at 60°—70°, and the upper eight inches of the coal is inferior.

In a stream entering the river about 350 yards from the boundary of the Tipam rocks, seams, 22″, 10″, and 18″ thick, respectively, dip to S. 55° E. at 40° to 60°. The 18″ seam outcrops at the mouth of the stream.

Dikhu left bank.

No coal-seams of importance are to be found in the numerous water-courses above Telpung on the left bank. Just below Telpung a large stream joins the Dikhu. In its bed fragments of coal are seen in several places, but the only outcrop discovered is at an elevation of 850 feet above the river: the thickness of coal is 20 inches, and the dip to S. 20° E. at about 20°.

In a tributary joining the main stream at its mouth a number of outcrops were found. This stream was known to Mallet as the Hil Jan (pp. 70-71). The thicknesses of coal are:—

	Ft.	Ins.	
No. 1—Poor Coal	0	6	
Coal	3	0	Dip S. at 20°.
No. 2—Inferior coal	0	6	
Coal with irregular dirt bands aggregating 4″ in thickness (sample No. 38) . . .	7	0	Dip S. 10° E. at 34°.
Carbonaceous shale . .	0	9	
No. 3—Coal	1	5	Dip S. 20° E. at 50°.
No. 4—Carbonaceous shale . .	2	3	
Coal with some shale . .	1	9	Dip S. at 45°.
Carbonaceous shale . .	3	0	
Coal	2	0	

	Ft.	Ins.	
No. 5—Carbonaceous shale . .	1	0	Dip S. 10° E. at 65°.
Coal	2	9	
No. 6—**Coal**	2	4	

Nos. 5 and 6 are close together. The rocks thereabouts are contorted and strongly impregnated with oil. Coal is seen again at several points further down stream, but none of the seams exceed 6 inches in thickness.

In a stream flowing into the Dikhu some 700 yards below Telpung, crushed and contorted coal-seams occur at two or three points. No seam of workable thickness was found.

In the streams below Namsang, Mallet (pp. 72-73) found four coal-seams aggregating 17 feet in thickness. They were not examined during the present enquiry.

QUALITY OF THE COAL.

The coals of the Jaipur and Nazira fields closely resemble in appearance those from the Makum area, but they are undoubtedly a little inferior in quality. They are bright black in colour, and usually display a cubical fracture. They burn readily with considerable flame and great heat. As pointed out by Mallet, they vary considerably in hardness, some of the coals being extremely hard and brittle, whilst others crumble to pieces when held between the fingers. I am not, however, inclined to emphasize this distinction, for in more than one instance I have noticed bands of hard coal represented by soft bands within a short distance. Experience at Makum has shown that the coal breaks up readily, so that as supplied to the consumer the general average size of the lumps is about a two-inch cube, and there is a large quantity of "small." I have little doubt that this would be the case in the Jaipur and Nazira fields. Many of the coals cake strongly, whilst others display only slight caking properties, or do not cake at all. There appears to be little, if any, relation between the hardness, the caking properties and the chemical composition.

The following assays of the coals were made by Sub-Assistant Sethu Rama Rao in the laboratory of the Geological Survey. The samples are true average samples of the seams, and were collected by myself:—

No.	Locality.	Section of Seam.	Ft.	Ins.	Moisture.	Volatile matter exclusive of sulphur.	Fixed carbon.	Ash.	Sulphur.	Caking properties.	Colour of Ash.	Remarks.
		THE JAIPUR COAL-FIELD.										
1	North of Dekhajoli tea-garden.	Upper coal band .	5	6	10·31	38·73	47·34	3·62	...	*Nil*	Buff	Coal soft and crushed.
2	1½ miles north-east of Tipam	Coal . . .	4	11	7·77	35·49	48·75	7·99	...	*Nil*	Grey-brown	Coal hard and bright.
3	Two miles south of Jaipur	Middle coal band	3	9	8·99	40·08	48·58	2·35	...	*Nil*	Buff	Seam contains 11 feet of coal in bands.
4	One mile north-north-east of Hapjan tea-factory.	Four bands of coal aggregating .	7	10	4·95	43·35	45·24	6·46	...	Cakes poorly	Do.	Coal hard and bright.
5	First stream north of Disang river.	Coal . exceeds	4	0	6·63	39·77	51·51	2·09	...	Do.	Do.	Hard bright coal.
		Shale and inferior coal.	4	0								
6		Coal . . .	15	0	4·75	45·10	47·95	2·20	...	Cakes well .	Dark-brown	Soft coal impregnated with petroleum.
7	Right bank of Disang river	Coal . . .	5	0	5·18	42·64	49·94	2·24	...	Do.	Brown-red	Coal soft.
8	Ditto	Coal . . .	8	0	5·12	44·73	48·74	3·41	1·84	Do.	Brown	Bright hard coal.
		Clay . . .	0	7								
9		Coal . . .	4	0	5·69	39·49	52·37	2·45	...	Cakes poorly	Dark-brown	Ditto.
10	Ditto	Coal . . .	4	3	4·81	40·28	49·71	5·20	...	Cakes well .	Do.	
11	Left bank of Disang river	Coal . . .	5	2	5·00	42·40	48·41	4·19	2·82	Cakes poorly	Grey-brown	Hard bright coal.
12	Ditto	Upper coal band .	3	11	6·44	40·60	49·60	3·36	...	Do.	Red-brown	Total thickness of coal 6′ 3″.

THE JAIPUR COAL-FIELD—*concld.*

No.	LOCALITY.	Section of Seam.	Ft.	Ins.	Moisture.	Volatile matter exclusive of sulphur.	Fixed carbon.	Ash.	Sulphur.	Caking properties.	Colour of Ash.	REMARKS.
13	Left bank of Disang river	Upper coal band	4	10	5·19	41·73	50·68	2·40	...	Cakes w	Grey-brown	Coal hard and bright. There are two lower bands of soft coal, aggregating 2′ 3″.
14	Ditto	Coal	2	3	4·81	39·49	48·59	7·11	..	Cakes	Grey	Soft coal. Shale band was excluded from sample.
		Shale	0 to 0	3 8								
		Coal	1 to 1	0 6								
15	Ditto	Coal	12	0	10·27	36·42	52·21	1·10	0·90	*Nil*	Brick-red	Coal rather soft.
16	Stream 1½ mile south-west of Disang river.	Coal	2	8	6·69	37·63	53·71	1·97	...	*Nil*	Dark-brown	Sample taken from the coal bands.
		Carbonaceous shale and shale.	2	0								
		Coal	2	0								
17	Ditto	Coal	1	9	8·06	37·50	47·52	6·92	...	*Nil*	Brick-red	Hard bright coal. Sample taken from the coal bands.
		Shale with bands of coal 3″ and 11″ thick.	4	2								
		Coal	3	6								
18	Ditto	Coal	3	6	6·73	40·35	47·95	4·95	...	Very slight	Brown	Hard bright coal. Sample from the coal bands.
		Shale with 5″ band of coal.	3	4								
		Coal	3	5								

19	Stream 4 mile south-west of Disang river.	Coal . . .	2	0	6·71	38·38	47·26	7·65	...	Cakes poorly	Light-brown	Sample from the coal bands.
		Shale with a 16" band of coal.	5	1								
		Coal . . .	2	8								
20	Ditto	Coal with a 2" band of coaly clay.	4	2	9·47	39·95	46·31	4·27	1·36	*Nil*	Buff	
21	Stream east of Borhatia	Coal . . .	12	0	5·42	43·50	48·55	2·53	2·43	Cakes poorly	Light-brown	
22	Stream south-east of Diopani East.	Coal . . .	3	4	6·28	38·49	51·42	3·81	...	*Nil*	Dark-brown	
23	Ditto	Coal . . .	3	6	8·19	35·67	52·39	3·75	...	*Nil*	Buff	Seam is bright and hard and is underlain by a foot of coal containing three half-inch bands of clay.
24	Stream near Terukia	Coal . . .	10	0	3·95	36·49	41·38	18·18	...	*Nil*	Light-grey	
25	Stream near Halua	Coal . . .	5	9	5·33	38·86	45·44	10·38	...	Slight	Brown-grey	Coal rather "weathered."

THE NAZIRA COAL-FIELD.

26	Landslip on north side of Bor Jan valley.	Coal . . .	1	2	5·08	42·90	46·73	5·29	3·27	Slight	Light-grey	Coal hard and bright.
		Dirt . . .	0	2½								
		Coal . . .	6	6								
27	Tributary of Bor Jan stream	Coal . . .	7	0	5·12	42·23	48·21	4·44	...	Slight	Light-brown	
28	Ditto	Coal . . .	4	3	4·85	38·39	48·52	8·24	...	Do.	Red-brown	Coal rather "weathered."
29	Tributary of Por Jan stream, near Kongan.	Coal . about	7	6	7·23	40·92	47·97	3·88	1·69	*Nil*	Brick-red	
30	Tributary of Wakting Jan stream.	Coal . . .	12	0	4·96	38·18	54·64	2·22	3·70	Cakes strongly	Brown	Coal hard and bright.

THE NAZIRA COAL-FIELD—*contd.*

No.	Locality.	Section of Seam.	Ft.	Ins.	Moisture.	Volatile matter exclusive of sulphur.	Fixed carbon.	Ash.	Sulphur	Caking properties.	Colour of Ash.	Remarks.
31	Tributary of Wakting Jan stream.	Coal . . .	13	0	6·84	35·33	53·29	4·54	...	Slight	Buff	Coal hard and bright.
32	Ditto	Carbonaceous shale with bands of coal.	23	0	4·21	21·18	28·51	46·10	...	Do.	Brown	This seam lies about 100 feet below the 13 feet seam.
33	Ditto	Coal . . .	7	0	4·38	37·36	53·46	4·80	4·27	Cakes strongly	Do.	Coal hard and bright.
34	Ditto	Coal . . .	5	0	3·89	39·65	49·84	6·62	...	Do.	Do.	Coal soft. This seam; lies about 100 feet above the 7 feet seam.
35	Ditto	Coal . . .	6	0	7·03	35·92	47·44	9·61	...	*Nil*	Buff	Coal rather "weathered."
36	Telpung stream	Coal . . .	4	6	3·90	36·16	45·49	14·45	...	Cakes strongly	Grey	Coal is bright and fairly hard.
37	Stream joining the Dikhu river above the Telpung stream.	Coal . . .	4	3	6·57	34·36	52·68	6·39	3·80	*Nil*	Dark-red	
38	Stream joining the Dikhu on the left bank just below Telpung.	Coal with two or three irregular dirt bands aggregating about 4" in thickness.	7	0	6·04	35·95	52·17	5·84	...	*Nil*	Dark-grey	It was not found possible to entirely exclude the material from the dirt bands.

Although a little inferior to the Makum coals, the chemical analysis shows that these coals are of excellent quality. The worst features are the somewhat high percentage of moisture and the large sulphur content. This latter feature will, I fear, prevent any extensive use of the fuel for coke-making. Analysis has shown that coke made from washed Makum "slack" coal contains as much as 2½ per cent. of sulphur.

WORKABLE AREAS AND QUANTITY OF COAL.

The original estimates by Mallet of the amount of workable coal in these coal-fields were 20 million tons for the Jaipur field and 35 million tons for the Nazira field. These figures take into account only a narrow strip measuring 150 yards or, as on the Dikhu, 200 yards in width.

As indicative of the great possibilities of the fields these figures may be allowed to stand, for during the recent explorations nothing has come to light which seriously impugns their accuracy. It may, however, be pointed out that in the Jaipur field the figures are based on a length of outcrop of only 15 miles, whereas more detailed work has shown them to extend for a distance of at least 25 miles. We must also take into consideration the newly discovered inlier south of Kanugaon and the outcrops on the Saffrai river near the Doodar Ali road.

I propose, however, to confine my estimates to certain areas which, from their strategic position or from the superior amount and workability of the coal that they contain, are of immediate practical importance.

Disang River—Borhat.

Situation, etc.

This area is situated on the south-west of the Disang or Dilli river, at a point near the deserted village of Borhat, and some five miles south-east of Dilli, Assam-Bengal Railway. Connection with the railway would present the minimum of difficulty, as owing to the existence of an ancient and abandoned embanked road, along which the rails could be laid, little or no earth-work would be required. No streams of importance would have to be crossed.

Number and thickness of the coal-seams.

The best, but at the same time an incomplete, section of the coal-measure rocks of the Jaipur field is to be seen in the banks of the Disang river. Ten seams, in all, have been discovered, and of this number six are of workable thickness and quality. Eliminating inferior coal and bands of shale and clay, the total thickness of coal is more than 45 feet.

In two streams, lying 1,300 and 1,700 feet, respectively, distant from the left bank of the river, four workable seams outcrop, the aggregate thickness being 18½ feet.

In five streams, distant from 3,000 to 5,000 feet from the river, some 16 feet of workable coal are found in from two to four seams.

To the immediate south-west only thin seams have been found, and it is fully a mile further on before coal of workable thickness is met with again.

Quantity of coal.

It is very probable that the coal-seams continue to be of economic value for many miles on either side of the limited area under consideration. But the probability of faulting on the east of the river imposes a limit in this direction, and in the opposite direction it will not be prudent to rely on a greater co-extension than that actually proved by the prospecting operations ; for it may be the case that the workable areas are isolated from one another by local impoverishment of the measures. The actually proved extension is about one mile, and throughout this distance a moderate estimate of the aggregate workable thickness of coal would be, say, 25 feet. The average dip is about 60°, and we may presume that a workable depth of about 500 feet would be easily attainable. With these premises the quantity of coal will be :—

Length × vertical depth × cosec. angle of dip × thickness × weight of one cubic foot of coal $= 5{,}280 \times 500 \times 1{\cdot}15 \times 25 \times \frac{79}{2240}$ $= 2{,}676{,}830$ tons, of which we may assume that 1½ million tons might be extracted profitably.

Method of working.

It should be clearly understood that the quantity of coal above water level is practicably negligible, and that any attempt to work this trifling amount, either by galleries or by quarrying, is fore-doomed to failure, and the effect of the experiment would be to throw a costly burden on subsequent operations in the shape of a heavy pumping bill.

The most satisfactory method of exploiting the area would be to sink a vertical shaft from which level stone-drifts would be driven to reach the coal-seams in depth. The underground roads would be so arranged that all the coal could be raised from this shaft, and it would also be the site of the main pumping installation. Auxiliary shafts for the purpose of ventilation, and as emergency exits, might be sunk on the plane of one of the coal seams; care being taken to choose that seam which possesses the soundest roof and floor, as well as a convenient thickness of coal. The site of the main shaft would be conveniently chosen about half a mile from the left bank of the Disang, a little outside the outcrop of the lowest seam found, and at a height sufficiently above the alluvial plain to avoid the difficulty of sinking through sand, and also to provide adequate head-room for screening operations, and tipping into railway wagons.

Apart from its uses for coal-winding and pumping, such a shaft would be of great prospecting value, for it would explore the rocks underlying the coal-seams of known outcrop, and possibly lead to the discovery of seams the outcrops of which are now concealed by the alluvial plain. Such exploration should be extended by level stone-drifts both towards the dip and rise of the rocks.

That such seams exist is beyond doubt, for in the Disang section the surface width of the band of rocks within which workable seams have been found exceeds one thousand feet, and there is a strong probability that, even here, the outcrops of higher seams are concealed by the alluvium; whereas in the stream sections to the south-west only about half this breadth is displayed.

The Saffrai and neighbouring Tea-gardens.

This area is the only one of those being described which lies within territory administered by the Government of India. It is situated in the neighbourhood of the Saffrai, at the point where that river crosses the main road, and within three miles of the Assam-Bengal Railway. Coal has been found with wide intervals over a length of about four miles. There are at least two coal seams, respectively, 3 to 4 feet, and 6½ feet thick, but little is known as to their extension. The dip of the rocks in those sections examined varies from 52° to 72°. The whole of the available coal lies below the level of permanent saturation, and no attempt can safely be made to estimate its amount.

Upper portion of the Saffrai Valley.

I did not visit this part of the Saffrai Valley, but according to Bruce and Mallet[1] (pp. 329—332) there are several thick seams of coal near the confluence of the Chota Taukak with the main stream and also south-east of Tirugaon. The beds, however, scarcely rise above the alluvium level, and the average dip is as much as 50°.

The locality is about ten miles from the railway over country offering no great difficulty to construction.

Dikhu River and its Tributaries

Situation, etc.

The coal in this locality lies from 11 to 12 miles south a little east of Nazira, Assam-Bengal Railway. A branch railway line, some seven miles in length, is already in existence as far as Santak on the right bank of the river. There would be no difficulty in extending this line for two or three miles to a point in the neighbourhood of Naginimora, and for the remaining distance wire-rope transmission could be easily and cheaply installed.

The elevation of the outcrops varies from nothing up to 1,700 feet above the river, and thus a large quantity of coal might be extracted from above free drainage level.

Number and thickness of coal-seams.

Bor Jan Valley :—Passing up the Bor Jan, or stream, the first coal-seam is met with soon after passing over the large fault forming the north-western boundary of the coal-field. It occurs in a belt of highly disturbed and occasionally inverted rocks flanking the fault, and it has been traced for nearly three-quarters of a mile to the south-west. Its thickness is variable, but a fair average will be 8 feet of coal.

The principal seam outcrops higher up the valley. It is contained within rocks dipping regularly towards the hills at an angle of about 30°, and it has been traced for a distance of nearly 1¾ miles at

[1] Mallet found but one seam from 5 to 6 feet thick. He accepts, however, Bruce's statements, and concludes that the outcrops of the thick seams are now covered up by alluvium.

elevations varying from 700 to 1,700 feet above the river. The thickness of coal varies from 4′ 2″ to 8′ 3″, the average being not less than 6 feet.

Some 250 feet vertically below this seam another coal-bed, from 3 to 4 feet thick, outcrops in two streams about 175 yards apart. Besides these beds there is a number of smaller seams from one to two and a half feet in thickness.

Wakting Jan Valley:—As in the Bor Jan the first seam encountered going up stream is contained in the highly disturbed rocks running parallel with the main fault. Its thickness is 13 feet.

About 150 yards further on, and at an elevation of 600 feet above the river, a regular series of rocks is found dipping into the hills at an angle of about 25°. They enclose a seam of coal 13 feet in thickness, the outcrop of which rises to an elevation of about 1,000 feet, and from thence falls steadily to the Dikhu, near Telpung, rising again up the opposite slope. This seam has been traced for more than 1⅜ miles. The full thickness of 13 feet is preserved for only one-eighth of a mile. Where next seen, some three hundred yards beyond, there are two seams, respectively 7 and 7½ feet thick, separated by more than 100 feet of strata. Beyond this there is a gradual decrease in thickness, the width of the seams on the Dikhu being 3 and 2 feet respectively.

Conformably overlying this seam, but separated by about 150 feet of strata, there is another coal band of variable section, the average thickness at points about 600 yards apart being about 5 feet. In addition there are numerous thinner seams of coal, probably too thin to be of economic value.

Method of exploitation and quantity of coal.

In preparing the estimates of available coal I propose to leave out of count entirely the highly inclined seams in the belt of disturbed rocks flanking the boundary fault. Probably a large amount of coal may be extracted from these seams, but the difficulties of working them will be considerable, owing to contortion and faulting. They are, however, well-situated for opening up, seeing that they head straight into the hill-sides. Consequently they might be relied upon as an immediate source of fuel until such time as arrangements are complete for establishing mines on the more regular deposits.

The obvious method of opening up these latter seams is to drive level rock tunnels from suitable points situated some distance below the lowest positions of the outcrops. These tunnels or adit-levels might be arranged to cut the coal-seams at points some 150 feet vertically below the outcrops, and by driving out levels in the seams the following quantities of coal might be extracted without recourse to pumping operations:

Bor Jan six-feet seam :—The length of the rock-tunnel would be about 600 feet. Presuming a dip of 30°, then, within 3,000 feet of the junction of the tunnel with the coal-seam, a strip averaging 600 feet[1] in width could be worked, the quantity of coal being :—

$3{,}000 \times 600 \times 6 \times \frac{79}{2240} = 380{,}893$ tons. Two-thirds of this amount or *250,000 tons* may be considered available.

Between 3,000 and 4,500 feet from the tunnel the workable strip averages 1,000 feet in width, and contains some *210,000 tons* of available coal.

Between 4,500 and 9,000 feet from the end of the adit a strip 1,800 feet in width is workable, the amount of available coal being more than *one million tons.*

Wakeing Jan thirteen-feet seam :—The dip being taken as 25°, the length of the rock-tunnel would be about 650 feet. Within 1,600 feet of the tunnel the thickness of the seam may safely be taken as 13 feet, and a strip averaging 800 feet in width would be workable, the amount of available coal being about *400,000 tons.*

Between 1,600 and 5,100 feet from the tunnel, the workable strip would average 700 feet in width, and, presuming a thickness of 6 feet, the available coal would amount to nearly *350,000 tons.*

Summarizing :—

	Tons.	Tons.
Bor Jan Valley	250,000	
	210,000	
	1,000,000	
	1,460,000	1,460,000
Wakting Jan Valley. . .	400,000	
	350,000	
	750,000	750,000
GRAND TOTAL .		2,210,000

[1] See levels on sketch map, Plate 27.

By the use of syphons delivering at the level of the river the amount of coal workable without resort to pumping, would be doubled. In addition to this there is a considerable amount of coal contained in subordinate seams and in the highly inclined seams flanking the great fault.

Comparison of the areas.

The respective advantages and disadvantages of the areas as the sites for the establishment of a working colliery are:—

Disang River—Borhat:—(1) The locality is only 5 miles from the railway, over easy country.

(2) There is an assured quantity of 1½ million tons of coal, with good promise of a larger amount.

(*1*) The seams are highly-inclined and possibly faulted.

(*2*) Practically the whole of the coal is below the level of permanent saturation, and thus exploitation would necessitate deep shafts and heavy pumping.

Saffrai and neighbouring Tea-gardens:—(1) The locality is not more than three miles from the railway, over easy country.

(*1*) No large quantity of coal has been proved.

(*2*) The seams are highly inclined.

(*3*) The coal lies below the alluvium level.

Upper portion of the Saffrai Valley:—(1) There are said to be thick seams of coal, but the outcrops are now covered up, the only seam which can actually be relied upon being from 5 to 6 feet thick.

(*1*) The locality is 10 miles from the railway, over country presenting no great difficulty to construction.

(*2*) The seams are highly inclined.

(*3*) The coal lies below the alluvium level.

Dikhu River and its tributaries:—(1) An assured quantity of 2,210,000 tons of coal, with great promise of a larger amount.

(2) The seams dip at an angle of from 20° to 35° only, and are much less disturbed than in any other area examined.

(3) The whole of the coal can be worked free from difficulties on account of water.

(4) The locality is from six to seven miles from the railway (at Santak), part of which is over difficult country.

Conclusion.

I am distinctly of the opinion that the latter area is the most suitable for the establishment of a colliery. The transport question is the only difficulty, and I am inclined to think it has been over-rated. Were it a question of adopting Mr. Lowther's plan of aligning a railway along the bank of the Dikhu, and from thence up the Borjan Valley, capitalists might well shrink from such an undertaking. The true solution, however, is telpherage, and there is not the slightest doubt that the output of the colliery could be cheaply and expeditiously dealt with by such means.

Before commencing operations it is essential that the services of a mining engineer of approved skill should be enlisted, in order that initial mistakes in the laying out of the plan of operations may be avoided. This latter is of vital importance to the future success of the undertaking.

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Kongan	26	45	94	53
Mattrapur tea-garden	26	58	94	58
Namsang	26	43	94	50
Nazira	26	55	94	47
Saffrai tea-garden	26	59	95	0
Telpung	26	45	94	51
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Tinsukia junction	27	28	95	25
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Tirukia	27	8	95	21
Wakting valley	26	45	94	52

NOTE ON THE MAKUM COAL-FIELD BETWEEN THE TIRAP AND NAMDANG STREAMS (SEASON 1905-06). BY R. R. SIMPSON, B.SC., *late Mining Specialist, Geological Survey of India.* (With Plate 30.)

Structure of the field.

ON page 34 of his report (*Mem. G. S. I.*, XII, Pt. 2, 1876) Mallet controverts a supposition of Medlicott's (*Mem. G. S. I.*, IV, 401, 1865) that the Tirap section is inverted ; he states : " I have not found any trace of the synclinal structure, implied in the supposition of inversion, along the inner zone of coal-measures, nor will the facts now known allow of this interpretation."

During my recent short visit to the area I found no reason to doubt the natural succession in the Tirap section, but, from my own observations, and from information furnished by the coal company working in the field, it is evident that the Tirap-Namdang area is a highly folded one.

The chief structural feature is that of a well-defined syncline, on the northern limb of which the company's mines have been excavated. This syncline is narrow and highly inclined on the west, but broadens out, with a decrease in the slope of the rocks, to the east. There is also evidence of subordinate folds. It is, however, unnecessary to go into further detail, as the structure is well illustrated by the map[1] and sections (Pl. 30).

Sections of the coal seams.

The following are measured sections of the seam, taken at points in the mines :—

Lower Ledo Mine.	ft.	ins.	*Namdang Mine.*	ft.	ins.
Coal	6	0	Coal	13	6
Shaly fire clay	2	6	Fire clay	7	0
Coal	9	0	Coal	14	0
Fire clay	3	6	Fire clay	4	6
Coal	3	0	Coal	16	0
Fire clay	0	6	Fire clay	10	0
Coal	8	0	Coal	4	0
	32	6		69	0

[1] Kindly supplied to me by the Assam Railways and Trading Co.

Lower Ledo Mine—contd.	ft.	ins.	*Namdang Mine*—contd.	ft.	ins.
Brought forward	32	6	Brought forward	69	0
Fire clay	3	0	Fire clay	2	0
Coal	2	0	Coal	10	0
Fire clay	0	3	Fire clay	3	6
Coal	4	0	Coal	22	0
Fire clay	0	3			
Coal	18	0			
	60	0		106	6
TOTAL COAL	50	0	TOTAL COAL	79	6
TOTAL FIRE CLAY	10	0	TOTAL FIRE CLAY	27	0

Analyses of the coal.

Below are given the results of analyses made by Sub-Assistant Sethu Rama Rao, Geological Survey of India, of carefully taken average samples of the total thickness of the principal layers of coal. They were collected by me from points in the mines close to the present working faces, and more than a mile from the entrances to the mines :—

No.	Locality.		ft. ins.	Moisture	Volatile matter exclusive of moisture	Fixed carbon.	Ash.	Sulphur	Caking properties.	Colour of Ash.	Remarks.
1	Upper Ledo colliery	Top coal .	12 0	1·97	40·72	55·87	1·44	1·75	Cakes strongly.	Dark brown	Bright coals with cuboidal fracture. Rather brittle.
2		Middle coal	7 0	1·67	41·93	52·60	3·78	3·57	Do.	Do.	
3		Bottom coal	30 0	1·76	39·50	56·18	2·56	1·91	Do.	Do.	
4	Tikak colliery	Upper Top coal .	5 0	1·92	38·09	58·68	1·31	...	Cakes strongly.	Grey .	Bright coals with cuboidal fracture. Rather brittle.
5		Lower „ „ .	12 0	2·26	36·37	59·32	2·05	...	Do.	Light brown	
6		Middle coal . .	12 0	2·33	36·95	59·93	0·79	...	Cakes	Brick-red .	
7		Upper Bottom coal	6 0	1·80	36·52	58·58	3·10	...	Cakes strongly.	Light grey .	
8		Lower „ „	12 0	1·91	38·45	58·03	1·61	...	Cakes	Light brown	
	Namdang colliery .	Coke made from washed small coal.		0·55	1·16	88·98	9·31	2·45	...	Do.	Manufactured in closed ovens, is in short thin prisms, and has a brilliant silvery lustre.

THE KABAT ANTICLINE, NEAR SEIKTEIN, MYINGYAN DISTRICT, UPPER BURMA. BY E. H. PASCOE, M.A., B.SC., *Assistant Superintendent, Geological Survey of India.* (With Plates 31—34.)

Previous observers.

THIS anticline, together with three others in close proximity and in more or less parallelism, was discovered in December 1905 by the Geologist to the Burma Oil Company, Mr. Macrorie, and his assistant, Mr. Boyd. They divided the country into square mile blocks, which, in the absence of mapped landmarks, will be useful for locating sections mentioned in this paper.

The axis.

The crest is found at a little less than half a mile east-north-east of Kabat (Thatekan: 21° 4′, 95° 20′ 30″) where it practically coincides with the boundary-line between blocks 18 and 19 (see map, Plate 31)[1]; its direction is here 27° west of north to 27° east of south. Passing southwards a few yards west of Payadaung Hill, it curves slowly towards the south, and in block 28 crosses the road between Seiktein and Myinthadaung at a little over half a mile from the intersection of this road and one running southwards from Kabat. There is no means of accurately locating the crest in this block on the map, and its position was estimated by timing the walk thence to the cross-roads and by counting the number of paces. North of Kabat it curves gradually towards the west, crossing the Chaung Ma in block 13 and the Taungkamauk Chaung close to the boundary-line between blocks 8 and 3, passing obliquely between the two villages of Taungkamauk North and Taungkamauk South, about half a mile west of the curiously beaked cone of Taungkamauk Hill. In the hilly and jungly country of block 1, its position can be determined by good sections in a stream valley not shown on any map. From several bearings taken with a compass, this position appeared to be in the western half of block 1. To the north and west of block 1, there is no diminution in the size of the hills, and in the sections in the water-courses here I could find no evidence of the anti-clinal crest sinking to any extent. Its direction here appears to be 30° north of west to 30° south of east. If its location on the map is correct, it may be advisable to add blocks to the north, north-west, and west of block 1, should oil be obtained in this neighbourhood.

[1] This map has been enlarged from the S. E. Frontier Sheet (1 in.=4 miles), geologically coloured by Grimes (*Mem. G. S. I.*, XXVIII, Pl. 3).

Nature of the anticline.

From what could be seen in the short space of a week, the anticline varies not only in direction but also in the nature of the fold. This is an asymmetrical one, and the eastern dips are everywhere greater than the western. We will consider first the excellent sections in the Chaung Ma, where the arch is beautifully shown (Plate 32). The bend is a sharp one: on a thin projecting ledge of limestone it is possible to walk up one slope and down the other in a dozen places. From the tip of the crest which can be located within two feet, 20 feet away to the north-east, the dip is 11°, at a distance of 60 feet it is 23° at 90 feet it is 46°, at 195 feet it is 64°, and further north-east it is still greater (Plate 33): in various bends of the stream dips rise to 74° and in one or two cases the bends are vertical or slightly reversed. Further down the stream towards the north-east, occurs the synclinal bend which is as acute as the anticlinal. Another beautiful section illustrates this at a sharp bend of the stream in block 19 (Plate 34). The strata of the high cliffs here dip at about 74° at the base, are vertical further up, and slightly reversed at the top: within a hundred feet or so of this cliff the dip is reduced to at most 15° (current bedding renders it difficult to determine exactly). Hitherto the direction of dip has been generally 27°—28° north of east, but on passing further to the north-east the sandstones become at first horizontal and then probably dip slightly in the opposite direction, forming an extremely gentle slope to a second anticline which here presents more the appearance of a monocline: the strata are so much disturbed by current bedding and so monotonous in character that only a general impression of west-south-westerly dip can be gained.

To return to the first or Kabat anticline, on passing westwards from the crest along the Chaung Ma, although the dip at a distance of 40 feet is 10°, this, instead of increasing, decreases slightly, and is apparently due to a slight collapse produced by the weight of the rocks. The beds of the south-western slope, like the corresponding ones of the second anticline, are monotonous and markedly current-bedded, so that few reliable dips are available, except where clay-beds appear. Dips from 3° to 10° and 14° can be obtained in various places, and the error will not be great in assuming that there is an average dip of about 10° which continues at least as far south-west as the Seiktein Chaung.

There is no evidence of faulting anywhere in the Chaung Ma. The crest is intact except for the intrusion of numerous small veins of calcareous mud or sand, from 1 to 2 inches thick, averaging about a foot apart, most of them more or less vertical, apparently radiating from the axis of the fold, to which they are very roughly parallel (Plate 32).

About half a mile south-south-east from this exposure in the Chaung Ma, the crest is again well exposed in the bend of a small tributary stream, and itself distinctly dips at 7° in a north-west direction, and from the direction of many dips taken further south in this small stream, there is a slight sinking of the crest in an opposite direction—*i.e.*, south-east—about four or five hundred yards away; so that there is a distinct local elevation of the crest here, which may have some significance should oil be obtained in this field.

In block 23 very few exposures were met with, but the anticline probably begins to flatten out here. In block 28, in a stream-bed at an estimated distance of a little over half a mile from the intersection of the Seiktein-Myinthadaung road and a road from Kabat, the crest can again be identified, though the exposures are not good. The following dips were observed :—

46°—direction 17° N. of E.
18°— „ 30° S. of E.
11°— „ 17° E. of S. close to the crest itself.[1]
10°— „ 55 W. of S.

indicating that the anticline is sinking. The hills in this region are lower.

Passing northwards from the Chaung Ma, very few sections occur between this and the Taungkamauk Chaung, though the strike of the beds can often be observed in the footpaths and roads, especially when passing over steeply-dipping strata.

In the Taungkamauk Chaung the exact position of the crest is difficult to identify. This may be due entirely to the obscurity of the beds in the jungle-covered banks, but there seems to be evidence of a sinking and broadening of the arch here. For two or three hundred yards the strata appear to be practically horizontal. It is true the sandstones here are current-bedded, but the above supposition is confirmed by the absence of any very great dips on the eastern slopes : the highest I could obtain was 33° in an east-north-east direction. It is

[1] The strike of the steeply dipping beds is 17° W. of N. to 17° E. of S.

possible that slightly higher dips do occur, but it seems improbable that dips over 60° could escape exposure at the surface in a stream bed. Proceeding further eastwards along this stream-bed, dips of the western slope of the "second anticline" soon begin to appear, and these, unlike those corresponding in the Chaung Ma, increase steadily, attaining a maximum of 26°—30°. The crest of this "second anticline" is also definitely recognisable here, and can be located within twenty or thirty feet The arch is broad but distinct, and not so flat as it appears to be in the Chaung Ma to the south. Further evidence that this "second anticline" is more elevated here, is found in the fact that monotonous greenish-yellow current-bedded sandstones, similar to those which form the crest in the Chaung Ma, are found in the Taungkamauk Chaung at some distance on either side of the crest, which is here composed of lower beds of clay, sandstone, and slabs of concretionary limestone. It would seem that the flattening of the Kabat anticline here has been compensated by the elevation of the "second anticline."

In block 1 and the hilly country to the north-west, although covered largely with dense jungle, there are many excellent exposures in the water-courses and valleys, but, without a single landmark shown on the map, it is impossible to indicate with any precision the position of sections. The following dips were taken in a stream-bed south-east of a high hill surmounted with a flag-post, outside block 1 and not very far from its north-western corner, starting from the crest and proceeding eastwards :—

Crest—probably horizontal.
15°—direction 30° E. of N.
40°— " 30° E. of N.
40°—45°— " 35° E. of N.
34°, 50°, and 65°, (all in one place—a small fault here, and much crumpling of beds).
46°—direction 20°—23° E. of N.
26°— " 17° E. of N.
30°— " 40° E. of N.
26°— " 23° E. of N.
35°— " 15° E. of N.

It will be noticed that in passing away from the crest, the dips in several instances become more northerly. If these are correct, a rise in the crest is indicated rather than a fall. However, the dips are very irregular both in magnitude and direction, and the country requires more detailed investigation before such a rise can be verified.

Physical features.

The contour of the ground is not always serviceable in deciphering the stratigraphy of the district. More often than not the crest coincides with low-lying ground: this is specially the case in the Chaung Ma area, where the sharpness of the bend has abnormally weakened the resisting power against denudation, and where also a good deal of easily removed clay occurs in the neighbourhood of the crest. In the extreme north the crest can be observed in the lower slopes and valleys connecting two hills, although in two cases at least it passes right through the centre of two high and extensive hills.

Perhaps a more constant feature of the landscape is the occurrence of a line of steep hills stretching along the eastern slope of the anticline, the north-eastern slopes often more or less coinciding with the dip and producing a regular smooth bank, whereas south-western slopes are usually more irregular and are more apt to show sections. South-west of the crest there is little to guide one; hills occur here and there with rounded slopes, which in most cases appear to have no connection with the stratigraphical structure.

The rocks.

The beds are fairly equally divided between sandstones and clays, the latter, if anything, predominating, and occurring a little more abundantly near the crest than in regions more remote. Near the crest and elsewhere are thin ochreous-green sandstones, which remind one forcibly of the oil-sands at Kodaung,[1] though it is doubtful whether they actually correspond to them. Nearly all the sandstones found in the neighbourhood—which appear to be of Upper Miocene age[2]—possess this green colour more or less in their interior, but through oxidation have become more and more yellow, reddish-yellow, or even white, on the surface. The sandstones are moderately firm; sometimes hard and laminated, weathering into brick-like blocks and producing the appearance of masonry, more usually non-laminated and strongly current-bedded

[1] Yenangyaung oil-field, Magwe district. The oil-sands here are described as Lower Miocene (Prome stage of Dr. Noetling).

[2] Corresponding to Noetling's "Yenangyaung stage," and the upper part of Theobald's "Pegu division."

Here and there they are monotonous and uniform, but in very few places is the monotony unrelieved by the presence of limestone nodules or boulders. These are of two kinds, both of which are apparently concretionary. The botryoidal or mammillated form is very hard and crystalline, blue-grey in colour, and varying in size from 5 or 6 inches to 3 or 4 feet across. The other form is a hard, slabby, crystalline limestone, usually not more than 6 or 9 inches thick and extending for several yards in flat slabs, which frequently stand out like buttresses or platforms from the softer rocks. They often occur along the same horizon, forming as it were interrupted beds. These slabs generally weather to a brown surface, though inside the colour is usually grey. A curious feature about these flat limestones is the beautiful ripple-marking[1] often to be seen not only on the upper surface, but also on surfaces within the slab which have become exposed by splitting. That these limestones are concretionary there is little doubt, as they extend for a few yards only and die out abruptly with rounded edges: in fact there is every gradation between these flat slabs and more or less spheroidal and ellipsoidal blocks of the same stone which occur in the same sandstones. The most logical conclusion seems to be that they are casts of ripple-marking in original sandstones which have been subsequently displaced by the limestone. Blocks of limestone also occur in the stream-bed, which exhibit well-marked planes of stratification, and in several cases distinct current-bedding. These fragments are grey-blue in colour, ring well under the hammer, and are often of large size. Whether they are to be regarded as detrital or concretionary is a matter for further research.

Another form, in which carbonate of lime occurs, is that of the cementing material in the curious, branching, tubular aggregations of sand, lying irregularly in a soft porous sand rock. These are in every way similar to those which are so typical a feature of the Pliocene[2] river cliffs at Yenangyaung, consisting of anastomosing branches which, on a weathered surface, project in the most fantastic patterns and remind one of certain forms of sponges. The tubes consist of coarse sand particles cemented together by soft white or pinkish carbonate of lime, the proportion of which increases from the

[1] Similar ripple-marking was noticed on similar slabs at Twingon (Yenangyaung) and at Minbu.

[2] *Mem. Geol. Surv. Ind.*, Vol. XXVIII, p. 47.

periphery towards the centre, until, around the minute irregular central cavity, it entirely replaces the sand. This central cavity is very frequently occupied by the brittle remains of dried plant fibres (probably roots). These sponge-like concretions are of recent origin, as Mr. LaTouche has found similar occurrences in recent alluvial and other deposits, and attributes their formation to roots of recent plants which have pierced the soil-cap and penetrated for some distance into the underlying sands. Particles of carbonate of lime disseminated through the sand rock are dissolved by the carbonic acid furnished by the decomposition of the roots, and are redeposited when the water holding the carbonic acid in solution evaporates. The porous Pliocene sands are particularly well adapted for this modification, which is, locally, of quite an important significance; I have never seen it in any abundance in rocks of unquestioned Miocene age. In the same loose sandstone calcareous matter is also found in very irregular strings and veins which may run parallel or obliquely to the bedding or current-bedding planes; small clay concretions are also common.

Of the argillaceous beds, it is not common to find unmixed beds of clay of any thickness, except in the curious, irregular pockets which can be found here, just as they can at Yenangyaung. A very common type of bed is that formed of thin alternating bands of clay and sand, varying from ¼ to 1 or 2 inches in thickness, producing the appearance of a well stratified rock, which at a little distance might easily be mistaken for shale. The clay itself is hard, easily cracked by the sun, and occasionally shows signs of an incipient fissility. In places, especially where freshly exposed, the colour is greenish, but more commonly it is the peculiar light-blue so characteristic of the clays in the Miocene of Yenangyaung. Selenite is abundant on the hill-slopes, but is rarely found in the water-courses: it appears to be confined to the clays.

In the extreme north of this fold, water-worn blocks and pebbles of a hard, impure, detrital limestone occur in the stream-beds and on the summits and slopes of the hills. This interesting rock consists largely of bryozoan and foraminiferal tests, the material of which has been replaced by brown oxide of manganese, while their interstices and the space immediately surrounding them are commonly occupied by ferric oxide. Fragments of brachiopods, pelecypods and gastropods are frequent. Another prominent feature, is the occurrence of fragments—possibly pebbles—of a felspathic sandstone, consisting of clear angular grains of felspar, often of large size and frequently showing twin-lamellation, with more or less accessory quartz, cemented together by oxide of manganese, which has in all probability replaced calcite, since this mineral formed the cementing substance in a few cases. One pebble of a fine sandy clay was observed. The general cementing material of the rock as a whole is calcite, but there is so much manganese that the rock is quite dark in colour.

Among the fragments scattered over the sandy bed of the Chaung Ma, beside the densely strewn rounded pieces of lava from mount Popa, two other occurrences are worth recording: these are two pieces of gneiss—probably Archæan—and some water-worn blocks of a fossiliferous limestone. The latter often contains pebbles, sometimes to such an extent as to form a calcareous conglomerate: the fossils consist of brachiopod, pelecypod and gastropod shells.

Another interesting accessory feature is the occurrence of ferrous sulphate in moist porous Miocene sand, about three-quarters of a mile west of the crest in the Chaung Ma. The salt is seen as an abundant light-green efflorescence, mixed with varying quantities of the white ferric sulphate, on the surface of the sand. The intensely bitter taste had been noticed by the Burmans, who make use of the compound for medicinal purposes. A filtered solution gave a distinctly acid reaction.

Alluvium.

Capping the Tertiary beds in the valleys, and often at some height above the present stream level, a rapidly accumulated alluvial detritusis nearly always to be seen. This consists of large rounded fragments of lavas, and angular blocks of limestone and sandstone, embedded in sand or clay, or a mixture of both.

Age of the rocks.

In spite of the resemblance of some of the lowest sands to the oil-sands, and the amount of clay present, I do not think any of the Lower Miocene is exposed here. Selenite, the characteristic feature of the upper stage, can be found *in situ* on the hills in many places, either immediately over the crest or very close to it. It is to be noticed that the ground, wherever damp, is covered with a white efflorescence of the same salt which Grimes found at Yenangyat,[1] occurring on the surface chiefly of the lowest beds of the Upper Miocene. This salt is very dense in the neighbourhood of the crest, and is often sufficient to conceal the

[1] *Mem. Geol. Surv. Ind.*, Vol. XXVIII, p. 47.

nature of the beds. It, however, occurs all along the margin of the stream bed, where it has evidently been re-deposited by the water.

At about a quarter of a mile north-east of the crest, where the abrupt synclinal folding takes place, a series of sandstones comes in which are probably Pliocene. The colour is of that warm tint which characterises the Pliocene—a light to reddish-yellow. The sandstone is soft and unvaried, the lines of stratification being obscured by pronounced current-bedding. Jutting out from the surface were several of the curious branching, calcareous concretions noticed above, often containing the remains of a plant. Add to this that a large fossil tree-trunk of well-silicified wood could be seen jutting out of the sands half-way up the cliff, and that the latter was capped by a deep-red alluvial sand and gravel similar to that covering the Pliocene just north of the Pin Chaung,[1] and the evidence seemed complete. The very fashion in which the practically horizontal sands had been denuded into series of fantastic rounded buttresses radiating from a common axis, suggested a Pliocene age. However, the following points made a decided opinion impossible:

(i) although the fossil trunk referred to was well silicified, the wood-structure was very obscure and the fibro-vascular bundles almost obliterated;

(ii) only three other trunks could be found in place. Two of them, found in a small tributary stream-bed, were similar to the above, the wood being unrecognisable: the third, from the Chaung Ma, shewed wood-structure in places, but the whole was much decomposed and only silicified in parts;

(iii) the sandstone was moderately fine;

(iv) the branching calcareous concretions were by no means numerous;

(v) in a sandstone not far east from the synclinal fold, possessing this general Pliocene-like aspect, I found a small clay pocket containing abundance of selenite.

There are a great many fragments of fossil wood in the stream-bed, some of which appear to be practically unworn. These, however, may have been transported from the Pliocene beds close at hand, to the west of the crest. The matter requires more careful consideration than could be given to it in the short time at my disposal. It is possible

[1] A few miles north of Yenangyaung.

that at the sharply-folded syncline there may be an unconformity, the beds to the north-east being Pliocene. The selenite-bearing clay pocket referred to may very probably represent a fragment of Miocene clay dislodged from a cliff and covered over by the Pliocene sandbanks.

The thickness of Upper Miocene exposed between the crest and the synclinal flexure is about 900—1,000 feet.

The beds at Seiktein, some three miles west of the Kabat anticline, are undoubtedly Pliocene, consisting of very coarse, almost pebbly, sand, with tubular calcareous concretions, spheroidal limestone concretions, pronounced current-bedding, and typical fossil wood.

Fossils.

The only organic remains found beside the shells in the limestones were: a doubtful black impression of a monocotyledonous stem on a limestone boulder, and the fossil wood already alluded to. Very irregularly shaped, somewhat highly-coloured patches in the current-bedded sand rock, are probably remains of wood: in some of these patches carbonaceous matter was present, in others a fibrous texture could be made out, and in all deep-red ferric oxide and calcite played prominent parts.

Vegetation.

Unlike the Miocene of Yenangyaung and Yenangyat, the beds here are covered with a variety of trees. *Acacia ferruginea* predominates, Euphorbias are not very plentiful, while, in the north especially, dense bamboo jungle conceals the streams and lower hill slopes, and many varieties of fairly large trees cover the hills.

Prospects of obtaining oil.

As an oil-producing country, the prospects would be very promising but for two circumstances. In the first place the locality is some distance from what has hitherto been regarded as the oil belt. But although this appears to coincide closely with the rivers Irrawadi and Chindwin, oil has been found in small quantities a few miles south of Gwegyo, as far as 20 miles east of the Irrawadi, so that the width of the belt may not be so restricted as some have imagined. Kabat is 28 miles eastwards from the river bank.

In the second place, the proximity of the extinct volcano, Mount Popa, which is 10 miles from Kabat, diminishes the prospects of successful boring, especially as there is good reason to believe that the age of the mountain is post-Pliocene. The stream-beds and hill-sides along the Kabat fold are full of fragments of andesite lava, but I could detect none of these in any of the Miocene or Pliocene beds. Furthermore, on marching from Seiktein up over a lower spur of Popa, after at least five miles of volcanic beds had been traversed, I came upon a large mass of Pliocene just past the village of Gyaingywa, consisting of the typical coarse sand with calcareous veins and strings: further on, not far from Popamyo, occurred another isolated mass of greenish-white Pliocene sands. Whether these occurrences are *in situ*, or whether they represent fragments detached by the explosion, their position confirms the view that the eruption took place subsequently to the deposition of the Pliocene strata.

About three-quarters of a mile west of the crest in the Chaung Ma, a pool was pointed out to me, in which gas used to bubble, but it is undisturbed at the present day.

Should this area prove to be a new oil-field, the eastern slopes of the anticline will probably be unproductive, except perhaps in localities where the arch is flatter and more symmetrical. The most likely places are about three or four hundred feet south-west from the crest, especially where the latter is elevated, as in blocks 13 and 18.

With regard to the "second anticline," the country bordering the Taungkamauk Chaung is more promising than that bordering the Chaung Ma. If oil is found in this anticline, it will occur at a lower level than in the Kabat anticline: the depths of the wells, in fact, will have to be considerable.

THE ASYMMETRY OF THE YENANGYAT-SINGU ANTICLINE, UPPER BURMA. BY E. H. PASCOE, M.A., B.SC., *Assistant Superintendent, Geological Survey of India.* (With Plate 35.)

Previous work.

THE oil-field of Yenangyat was investigated and described preliminarily by Dr. Noetling (*Mem. Geol. Surv. Ind.*, Vol. XXVII, part 2, p. 124) and in detail by Mr. Grimes (*Mem. Geol. Surv. Ind.*, Vol. XXVIII, part 1, p. 30), who in the same paper has also dealt with its continuation across the Irrawadi, close to Singu.

An interesting point, which seems to have escaped the notice of both observers, is the effect of the asymmetry of the anticlinal arch upon the shape and position of the oil-pools, and upon the apparent direction of the axis.

Sequence of gas, oil, and water.

The rule that the crest of an anticline is occupied by gas—if any occurs in the field—and that first oil and then water are found in the same bed, consecutively, further down the anticline, is only approximately true for the oil-fields of Burma. It is true that as a general rule the occurrence of water in any quantity in a boring is a sign that the boundary of the oil pool in this particular sand has been exceeded, the site being too far down the anticline ; anomalous cases of water occurring above, and in contact with oil, have been reported in the Yenangyaung field,[1] but these rest entirely on the evidence of the well records, which are not always trustworthy.

With regard to gas, however, anomalies are more frequent, and the above rule can hardly be said to hold good. Wells drilled on the crest in the Singu and Yenangyat fields have, with few exceptions, proved to be void of gas or oil, or yielded either or both in small quantities only. The reason for this will be discussed later, but the fact to be pointed out here is that in a given transverse section of the anticline the proximity of any well to the crest has little or nothing to do with the *relative* amounts of gas and oil supplied by that well, unless such a section passes through or close to a point of maximum elevation of the crest ; a good example of the latter is furnished by a well close to a maximum crest elevation on Moksoma Kon, Singu, which has yielded enormous supplies of gas. It appears

[1] Noetling, *Mem. Geol. Surv. Ind.*, Vol. XXVII, part 2, p. 71.

that gas and oil are so intimately associated that a rich oil supply is most frequently accompanied by a rich gas supply, the effect of the latter often being to cause the well to "flow." Speaking generally, the richest wells, with respect to the yield of either gas or oil, are found to occur along a belt parallel to the general direction of the anticlinal axis: in the symmetrical Yenangyaung arch this belt is broad and lies along the crest, but in the Yenangyat-Singu field, where the easterly dips are much greater than the westerly, it is narrower and occupies a position some distance west of the crest. Thus in passing up the western slope of the Yenangyat-Singu anticline, we find the wells increasing in richness until this belt is reached; beyond this, eastwards, there is a very rapid decrease in the supply, which is exhausted before the crest is reached. There are local exceptions to this, but these correspond to modifications of the typical asymmetrical folding.

Experience has shown that in Burma it is generally safe to conclude that oil, owing no doubt to its specific gravity being less than that of water, will rise to the highest level possible, which would naturally be the anticlinal crest, except in places where this is already occupied by gas in any quantity.

Best sites for wells at Yenangyat.

At first the fact, now well known and well proven, that the most advantageous situation for a well-site in the Yenangyat-Singu or Singu oil-field is 300 or 400 feet west of the crest, was attributed to the rule concerning the sequence of gas, oil, and water in the anticline. This hypothesis, rendered doubtful in the first place by the failure to demonstrate any such sequence in the already exploited Yenangyaung field, had to be abandoned when it was found that borings closer to the crest did not tap the expected gas supplies, and that "crest wells" were often "dry" or unremuneratively productive. Grimes suggested another explanation (*Mem. Geol. Surv. Ind.*, Vol. XXVIII, Part I, p. 50), *viz.*, that the occurrence of the best wells about 400 feet west of the crest was "possibly due to the beds at the centre being somewhat broken up, so that the oil is partially diffused through the adjoining beds." There is very little evidence indeed of any such fracturing, and the following seems to me a simpler and more supported theory, the various points of which have been illustrated in the accompanying diagram.

Subterranean crests.

The Yenangyat-Singu fold is a very asymmetrical one, the easterly dips greatly exceeding the westerly. Using the term "crest" to denote that point on the anticline where the strata become horizontal, it will be evident that the actual *apex* of the fold must lie a little to the east of the crest. Now the locus of the apex of each of the various beds below the surface is approximately a plane, which is not vertical—as it would be in a symmetrical arch like that of Yenangyaung—but pitches or hades towards the west. The angle made by this plane, which we may term the "apex-locus," with the vertical, is half the difference between the eastern and western dips. This angle may be conveniently called "the hade of the apex-locus."

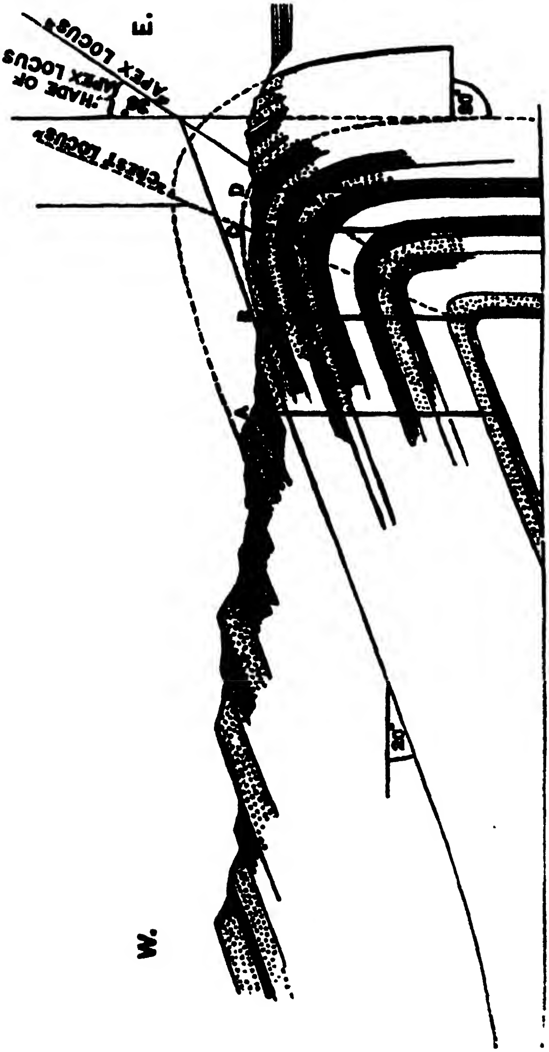

FIG. 1.—*Diagrammatic section to illustrate the probable structure of the Yenangyat-Singu anticline.*

Maximum westerly dip = 20°. } Hade of apex-locus = $\frac{90°—20°}{2}$ = 35°.
" easterly " = 90°.
Hade of crest-locus = about 25°.

A = a well which has missed the two upper "oil-pools," but derives a moderate supply from the 3rd.
B = a well which has passed through the margin of the 1st "oil-pool," derived a moderate supply from the 2nd, and when subsequently deepened, has tapped a rich yield from the lowest "pool."
C = a shallow crest-well which, after tapping the uppermost small "pool," was deepened unsuccessfully.
D = a well east of the crest, which has missed the three oil-pools, and, like C, has been confined after reaching a certain depth, to one bed of clay.

In the same way, the locus of the *crest* of the series of beds is a surface, the higher portion of which we will assume to be a plane, and although it does not necessarily follow that because there is a hade of the apex-locus there must also be a hade of the crest-locus, there is good evidence that such a hade does occur. Admitted that it is possible to construct a transverse section of an asymmetrical anticline in such a way that the series of crests or horizontal parts of the various strata lie vertically below one another, nevertheless it is unlikely to be the general case in such a sharp plication as that of Yenangyat, and a hade of the crest-locus is more probable. In consequence of this hade, the crest formed by any subterranean horizon, such as an oil-sand, would lie, not vertically beneath, but to the west of the crest exposed at the surface; and, further, the extent of this horizontal westward displacement would depend upon the magnitude of the "hade of the crest-locus" (or degree of asymmetry), and the depth of the horizon in question.

Evidence.

Enquiries from practical men in the field, as well as evidence from well-records, maps, and actual sections, showed that the facts agree fairly well with these conclusions. Firstly, the displacement can be observed in natural sections and is especially well illustrated in an exposure near Lanywa. Secondly, where the anticline is more symmetrical and the hade of the crest-locus consequently smaller, the richest wells tapping the same oil-sand are closer to the superficial crest than they are elsewhere. Thirdly, it has been found that the distance from the crest most suitable for a deep well is greater than that for a shallow well. Fourthly, considerable difficulty has been experienced by reliable expert workmen, in drilling a straight hole in some bores sunk on the visible crest, and this, I think, is due to the fact that the drill has passed into the steeply dipping easterly beds, and is therefore being constantly deflected. In places where the easterly beds are vertical, a hole bored on the crest would ultimately be confined to one stratum, to the bedding-planes of which it would be parallel. The otherwise unaccountable fact, that no oil whatsoever has ever been obtained in the Yenangyat field east of the crest, is readily understood when it is realised that the greater the depth of such a boring, the greater the distance eastwards from the subterranean crest formed by the oil-sand; no doubt many of the yielding wells drilled a short distance west of the crest, derive their supplies from the easterly dipping slope of the oil-sand below.

Another fact attributable to the asymmetry of the fold is that rich supplies of oil do not occur vertically over one another, and cannot be tapped by the same well, as they so frequently can in the Yenangyaung field. So far as an east to west position is concerned, the best site for a well to tap a given oil-sand of known depth might be calculated by the judicious use of the following formulæ :—

$$l = d \tan h + \lambda$$

$$\text{or, } l = d \tan \left(\frac{e-w}{2}\right) + \lambda$$

where l = the horizontal distance of the site west of the superficial apex, d = the depth of the oil-sand at the site, h = the hade of the apex-locus, e and w are the maximum dips (not due to minor puckers) of the beds on the east and west, respectively, of the axis, opposite the location,[1] and λ = the distance between the underground crest and apex—a space of a few yards, to be guessed from general considerations as to subterranean stratigraphy. The position of the anticlinal apex can be located by finding a place east of the crest where the dip is at right angles to the hade of the apex-locus, *i.e.*, is equal to $90° - \frac{e-w}{2}$. Unfortunately the crest is often so close to the river that *maximum* easterly dips cannot be obtained. There are insufficient data to show whether the crest-locus is ever parallel to the apex-locus.

Oil-pools.

Grimes in his memoir has calculated the position on the map of numerous points north and south of Yenangyat village, where the level of the "first oil-sand" is equal to its level in well No. 6 (B. O. C.). This well yielded only a small quantity of oil, and was assumed to be situated over the margin of the oil-pool. By joining up all consecutive points by a red line (see map, *Mem. Geol. Surv. Ind.*, Vol. XXVIII, part 1, plate II), he obtained a narrow closed area which, he concluded, embraced approximately all land which could "be exploited with hopes of success." In the subsequent development of this field, this prognostication has been found to be a little wide of the truth: both boundaries indicated, especially the eastern, are too far to the east. Grimes evidently assumed that the underground crest formed by the oil-sand was vertically below the exposed crest, and therefore located

[1] Where the easterly beds are reversed, e will be greater than 90°.

the eastern boundary of his petroliferous area east of the exposed crest instead of to the west; through the same error he also assumed that the oil-pools of the various oil-sands would be vertically above one another, and that the western boundaries of oil-pools below that tapped by well No. 6 would be practically the same in plan as that of the "first oil-sand." His western boundary should be correct as far as the "first oil-sand" is concerned, but the eastern boundary should be on the west side of the crest; this boundary should be well defined on account of the steepness of the easterly dips.

The horizons and extent of the various oil-sands are not always constant, and to map the limits of these would be a matter of considerable difficulty: the areas thus obtained would lie more and more towards the west the deeper the sand, and would not necessarily be of equal width, since the deeper pools are often richer and more extensive.

Direction of the axis.

The line joining exposures of the superficial crest exhibits considerable irregularity in direction, and it would at first sight appear that the anticlinal axis is by no means straight but winds about in a tortuous irregular manner (see map, Plate 35). In consequence of the "hade of the crest-locus," however, the course of this line will not coincide with that of the true anticlinal axis, but will be affected by the surface irregularities of the ground, and by the rise or fall of the axis itself. The country is extremely hilly and much dissected by ravines, so that there may be differences in height of 800 to 1,000 feet between two adjacent localities. Since the "hade of the crest-locus" may be as much as 48°, as it probably is in the north of the field, the horizontal displacement of the line joining crest exposures, whose levels differ by 1,000 feet, would be over 1,100 feet: in other words, this line would be bent out of a straight course to the extent of 1,100 feet. Although the majority of crest exposures mapped by Grimes occur on the hills, I think that most of the minor irregularities of the *apparent* axis-line (*i.e.*, the line formed by joining these exposures) may be attributed to horizontal displacement caused by difference in the level of the ground surface.

The direction of this crest exposure line will also be influenced by the rising or sinking of the anticline, since the average height of the ground in the neighbourhood of the crest—especially when this is close to the river—varies but little from block to block. As the anticline rises, the line will diverge more and more from the *true* axis-line, since the ground does not rise equally, and *vice versâ :* some at least of the more extended deflections of the Yenangyat-Singu crest exposure line are no doubt due to this, as a glance at the map will show. From the extreme south of the Yenangyat area the crest rises northwards, gently at first, but rapidly as it approaches the southern part of block 9, after which it falls rapidly and continuously as far as the centre of block B : thence it again rises steadily until a maximum is reached, probably in block 67 : whether it commences to sink again here to any extent, or remains practically horizontal for some distance northwards, has not been satisfactorily decided. Now the variation in direction of the line joining crest exposures corresponds generally with this rise and fall of the crest. From block E to opposite block 12 it is fairly straight except for a slight westerly sinuosity in block 13 caused by the low ground in the centre: in blocks 11 and 10 it is curving more towards the west, but ceases to do so in the south of block 9, where it rather abruptly turns northwards and curves towards the east as far as block B : thence northwards there is a general westerly tendency, but the correspondence of the two phenomena is obscure here, possibly because a rise in the level of the ground accompanies the rise of the crest and probably compensates more or less the effect of the latter. The westerly sinus in blocks 2 and 4 is due to low ground. There is reason to believe that the bend of the crest exposure line in block 57 indicates an actual deflection of the true axis, since there is a broad fan-shaped uplift in the ground east of the bend, the point of the fan coinciding more or less with the bend. In the Singu area, from the outcrop of the crest on the low-lying riverfront in block N, the crest exposure line curves round from a north-north-west direction more towards the south as it passes through higher ground : in crossing the valley of the Kyibin Yo, there is a pronounced sinuosity towards the west : in approaching Moksoma Kon in block 58 where the crest again rises to a maximum, there is a distinct bending southwards. Beyond this the position of the crest has not been mapped.

The variation in *degree* of the asymmetry of the flexure would also influence the direction of the crest exposure line, but its effect is nearly always to augment that of the rise and fall of the anticline, since a greater crest elevation is usually accompanied by a greater difference between easterly and westerly dips.

All these considerations point to the conclusion that the true anticlinal axis is much straighter than it would appear to be from a geological map; its true direction is parallel to the strike of the easterly dipping beds where these are vertical.

This subject of the effect of the "hading of the crest-locus" is of great importance from a practical point of view, not only in locating well-sites, but in estimating the value and prospects of the various demarcated areas in the field.

THE NORTHERN PART OF THE GWEGYO ANTICLINE, MYINGYAN DISTRICT, UPPER BURMA. BY E. H. PASCOE, M.A., B.SC., *Assistant Superintendent, Geological Survey of India.* (With Plates 36 and 37.)

Previous publication.

THE Gwegyo anticline was examined by Mr. Grimes in 1898,[1] and geologically mapped on a scale of 4 miles to the inch.

For industrial purposes, the northern portion of the Miocene outcrop has been divided into square-mile blocks, four of which are indicated on the accompanying map (Plate 36).

Character of the rocks.

The Miocene beds consist of olive-coloured sandstones and shales, the latter decidedly predominating. In places the shales are of a dark steel-blue, and since these were found at widely separated horizons and in fresh fractures or sheltered spots, it is possible that the olive colour is produced by oxidation, and that steel-blue is the primary colour. The shales are well laminated and fissile, and contain abundance of selenite: associated with them also in some places is white opaque calcite with crystal faces. The sandstones are moderately hard, and the steepness of the hills is due to the caps of sandstone protecting the shale beneath.

Age of the rocks.

It is doubtful whether any Lower Miocene strata are exposed here, as the blue colour of some of the shales appears to be due to protection from oxidation, and is moreover unlike the peculiar blue of the lower stage at Yenangyaung.

The white efflorescent salt (chiefly sodium sulphate) mentioned by Grimes as occurring at Yenangyat—typically over the lower beds of the Upper Miocene—is to be seen here and there in this district, but was not plentiful at the time of my visit, possibly because the ground was very dry.

The Pliocene[2] where it borders the Miocene consists of white coarse soft sandstone, with strings and thin veins of calcareous concretionary matter and spheroidal concretionary boulders; it can be

[1] *Mem. Geol. Surv. Ind*, Vol. XXVIII, Pt. I, p. 68.

[2] Irrawadi series (Noetling)

easily distinguished from the Miocene by its bright colour and by the characteristic compound-buttressed effect produced by denudation (Plate 37, fig. 2). The Pliocene hills are also much less rugged and steep. The unconformity between the two series, if existing at all here, is probably only a small one.

The anticline.

Although from the shape of the Miocene exposure the general trend of the anticline appears to be north-north-west to south-south-east, in the two blocks A and B where the crest is exposed its direction is practically due north and south. That the arches observed in sections here are really portions of the crest and not a result of the bending down of the strata-edges on the upthrow side of the neighbouring strike fault (see map, Plate 36), is, I think, established by the fact that they are almost confined to the easternmost portions of blocks A and B, and are sometimes at some distance, comparatively speaking, from the belt of the disturbed and broken upturned Miocene. Since the Miocene area is bounded in the northern part by Pliocene, and in the southern part by Recent deposits,[1] it seems probable that the crest reached a maximum height somewhere in the neighbourhood of Ayadaw or Nyaungnigyin.

According to Grimes, the eastern slope of the anticline is steeper than the western, but the fault is so close to the crest—at least in the north—that this is difficult to make out. Moreover, even where easterly dipping beds are seen on the upthrow side, it is impossible to say whether their dip is what it was before the fault was produced, or whether it has been increased, or actually produced, by the subsequent fracture.

In one good exposure in a tributary water-course east of block B, and very close to the north-east to south-west dip-fault, the crest is sharp and pointed: the beds on the west dip at a considerably greater angle than those on the east, and are rather abruptly succeeded by horizontal beds (Plate 37, fig. 1). There is either a small subsidiary synclinal fold or an actual fracture here, the effect possibly of the large dip fault, during the formation of which the edges of the westerly dipping beds have been dragged down at a point a few yards west of the crest, the westerly dips east of this point being increased and those west of the point being diminished practically to zero. Northwards the crest flattens somewhat rapidly, and just south-west of Tetma becomes

[1] See Grimes' map—*Mem. Geol. Surv. Ind.*, Vol. XXVIII, Pt. I, Pl. III.

very broad. In one section in a small water-course in block A, a small oblique fault traversed the crest, and the latter was further disturbed by what appeared to be a small parasitic fold on the eastern aspect.

The chief feature of interest in this region is the series of faults

Faults.

which run parallel to the irregular eastern margin of the Miocene. As far as could be seen, these faults meet but do not cross each other to any extent, in other words, the beds on the east, still covered by Pliocene, have sunk as a whole. Nevertheless the effect of the north to south fault in block C seems to have been produced into block B in the form of a fold, for a section in the stream-bed here, in a line with this fault, shows a small but sharp monoclinal fold in the westerly-dipping beds, the fold pitching towards the east or downthrow side. The effect of this north to south fault also appears to be continued southwards across the north-west to south-east fault in the form of a small fold. At any rate this may be the explanation of a section in the Pyinma Chaung in block D, in the form of an arch, which, but for its position, might be taken for the crest: or it might, with equal possibility, be a case of the bending down of the broken edges of the strata on the upthrow side, caused by the strain of the fault.

The faults, one of which can be seen in the cliffs near Nyaungnigyin, hade towards the downthrow in a normal way, *i.e.*, towards the east, but the hade is probably small. The throw, on the other hand, must be considerable. firstly, because so much of the Miocene is exposed on the upthrow, and none—*i.e.*, no unbroken beds—on the downthrow; secondly, because between the faults on the one hand, and the boundary line between Miocene and Pliocene on the other, occurs a broad strip of disturbed Miocene beds, which have been turned up and broken off from the downthrow side and now remain in a vertical position or dipping steeply to one side or the other. "Slickenside" can often be made out in the shales. The structure is well demonstrated in an east to west water-course in block C. Hard sandstones dipping about 35° west suddenly cease in an irregular cliff, against which are opposed beds of shales either vertical or dipping steeply to the east: proceeding farther to the east, we find the shales more or less continuous, with hard slabby sandstones here and there, dipping steeply now to the west, now to the east; then the dips are all to the east and become less and less, until finally the Pliocene is reached, which here dips at 38°—40° E.; the distance between the fault and the Pliocene boundary is 250 yards.

The disturbance by no means ends at the boundary however. East of Ayadaw, for instance, the Pliocene beds are turned up in a similar manner, dipping eastwards, and the normal westerly dips begin at a distance of 1,400 yards from the village, so that the effect of the fault can be traced for at least 1¼ miles. The extent of the effect here may perhaps be partly ascribed to the broad promontory-like or peninsular shape of the downthrow outcrop.

There is very little evidence of the bending down of the broken edges of the strata on the upthrow side.

The disturbed area of broken Miocene beds in blocks B, C, and D, is from 200 to 300 yards broad, but narrows as we pass northwards towards Tetma, the fault approaching the Pliocene boundary. Assuming the distance between the crest and the western boundary of the Miocene to be two miles, and the average dip westwards to be 30°, the throw of the fault must be over a mile.

Prospects of obtaining oil.

With regard to the prospects of obtaining oil in these blocks, I think it is safe to say that there will never be any well-defined oil-field around and to the north of Ayadaw. Wherever the crest can be located, the fault is found a few yards further on, on one side or the other, and probably in many places the two coincide: moreover just where the crest is rising to a maximum, it is cut transversely by the north-east to south-west fault in block B. In three or four places there appears to be evidence of minor faulting and disturbance: this would be most likely to occur at any points of maximum elevation of the crest, since these would be points of weakness.

The only hopes of successful boring are based on the following chances :—

(i) that there may have been originally some oil-pool sufficiently isolated to be unaffected by any dislocation at the crest;

(ii) that small intact portions of the crest may have been sufficiently convex in a north and south direction to retain any pre-existing oil, or any oil which collected subsequently to the formation of the fault;

(iii) that in the formation of the fault, the beds on the upthrow side may have been bent down to form a quasi-crest, beneath which oil may still remain;

(iv) that the abundance of argillaceous material may have effectually plugged the fault fissure in places and so prevented the oil from escaping;

(v) that the fault, occurring along, and hading away from, the *exposed* crest, may have left portions of the subterranean arch intact at petroliferous horizons.

(i) is improbable, as the different beds are, comparatively speaking, fairly constant and extensive, so that most of the oil would collect beneath the crest. The constancy of the beds is well exemplified by the uniformity in height, and regularity in direction of the hills. The same dip-slope can be seen for over a mile in block C, and the top of this range of hills is almost level;

(ii) and (iii) are also not very probable;

(iv) is practically the only chance which offers encouragement to prospect this area. It is just possible that the large amount of clay and shale may have blocked up the fault fissures, and to some extent prevented the escape of petroleum. That the latter has at one time or another existed here is a fact, since it has been seen at the surface in various places close to the faults. Whether the oil-sands are worth working is another question: at Talainggan, in the extreme south of this anticline, oil has been met with in borings, though not quite in paying quantities;

(v): this chance is spoilt—in this northern portion of the anticline at least—by the presence of the oblique north-east to south-west dip fault in blocks B and C. If the crest still remains in any part of the country south of Ayadaw, undisturbed by any transverse fault, the area might be worth testing; especially if it be true that the eastern slope of the anticline is steeper than the western, in which case the subterranean crest would occur further westwards and therefore at a greater distance from the fault than the superficial crest. Mr. Grimes may have had this possibility in view when he said: "the chances of finding oil by boring between Ayadaw and Gwegyo are not hopeless."[1]

[1] *Mem. Geol. Surv. Ind.*, Vol. XXVIII, Pt. I, p. 69.

BREYNIA MULTITUBERCULATA, AN UNDESCRIBED SPECIES FROM THE NARI OF BALUCHISTAN AND SIND. BY E. VREDENBURG, A.R.S.M., A.R.C.S., *Geological Survey of India.* (With Plate 38.)

THE highly specialised spatangoid genus *Breynia*, established by Desor in 1847 for the recent *Spatangus Australasiæ* Leach,[1] was first observed amongst the fossil forms by d'Archiac who described *Breynia carinata* from the Tertiary of Western India.[2] This fossil was figured in the Description des Animaux fossiles du Groupe Nummulitique de l'Inde, in which work mention is made of a second species, *Breynia sulcata* Haime, also regarded as nummulitic.

With the general adoption of Lyell's tripartite classification of the Tertiary, it became customary to group the whole of the nummulitic with the eocene. This accounts for the statements met with in palæontological treatises as to the occurrence of the genus *Breynia* in the eocene,[3] thus extending its range in a manner that scarcely harmonises with its specialised characters on the one hand, and, on the other hand, with the remarkably consistent evolution of the echinoid types through successive geological ages. When studying the palæontology of Java, Jenkins in 1863 noticed that amongst forms related to some of the fossil mollusca described by d'Archiac and Haime in the nummulitic fauna of India, there were representatives of a fauna newer than that usually classified as eocene.[4] Jenkins therefore regarded some of the beds in Java as miocene, and was followed by Duncan in his description of certain corals from Sind.[5] From their study of the fauna described in the Monograph on the nummulitic fauna of India, d'Archiac and Haime had already come to the conclusion that several horizons were represented by these

[1] *Ann. Sc. Nat. Zool.*, sér. 3, Vol. VIII, p. 12.
[2] Histoire des progres de la Géologie, Vol. III, p. 251, 1850. Description des Animaux fossiles du groupe nummulitique de l'Inde, p. 216 (1853).
[3] Zittel's *Handbuch der Palæontologie*, Vol. I, p. 544 (1876), French edition, p. 550 (1883).
[4] On some Tertiary Mollusca from Mount Séla, in the Island of Java. *Quart. Journ. Geol. Soc.*, Vol. XX, (1864) p. 45.
[5] A Description of, and Remarks upon, some Fossil Corals from Sinde. *Ann. Mag. Nat. Hist.*, ser. 3, Vol. XIII, p. 295 (1864).

fossils. Their opinion was confirmed by Blanford at the time of the detailed geological examination of Sind. In addition to undoubted eocene beds, the marine strata were found to contain some older horizons attributed to the Cretaceous, and newer ones the upper zones of which were designated as the Gáj group and regarded as miocene. It is these beds that correspond with some of the horizons recognised in Java, and which contain d'Archiac's species *Breynia carinata.* Blanford expressed more hesitation regarding the Nari group intermediate in age between the Gáj and the undoubted eocene beds, suggesting with some reserve that it might belong to the intermediate oligocene division which Beyrich had added to Lyell's classification. When describing the fossil corals and Echinoidea of Sind, Duncan and Sladen accepted with more confidence the oligocene age of the Nari, but still maintained the Gáj within the miocene, and even stated that they did not consider it to belong to the older part of that period.[2] In Duncan's Revision of the Genera of Echinoidea, the genus *Breynia* is stated to have first appeared in miocene times, the species previously classed as eocene having been proved either to belong to higher horizons, or to have been wrongly identified generically.[3]

Supported by so many published statements, the miocene age of the Gáj has been widely accredited, and this stage has come to be regarded as the leading type of the miocene of Asia.[4] Recent investigations have shown that the beds in Java synchronous with the Gáj of India belong to an older period than that hitherto assigned to them.[5] Strata situated at a high horizon of the Gáj of Sind are crowded with large lepidocyclines belonging to the group of *Lepidocyclina marginata.* True Burdigalian beds overlie the Gáj horizon in Balúchistán and Burma, while the Gáj itself is closely connected with the underlying Nari. This division therefore must be regarded as constituting the upper part of the Aquitanian, the Nari and Gáj together representing the bulk of the oligocene.

[1] *Mem. G. S. I.*, Vol. XVII, p. 32 (1879).

[2] Sind fossil Corals and Alcyonaria, *Pal. Ind.*, Ser. XIV, Vol. I, pt. 2, p. 104 (1880). Fossil Echinoidea of Western Sind, *ibid*, pt. 3, p. 274 (1885).

[3] *Journ. Linn. Soc. Zool.*, Vol. XXIII, p. 263 (1889).

[4] This is the interpretation usually accepted in general treatises and text-books. See, for instance, de Lapparent's *Traité de Géologie*, 4th edition, p. 1537 (1900), where these beds are regarded as possibly helvetian, and certainly miocene.

[5] H. Douvillé: Les Foraminifères dans le Tertiaire de Bornéo, *Bull. Soc. Geol. Fr.*, Vol. V (4), p. 435 (1905).

A species of *Breynia* from Tunisia, *Breynia Meslei* Gauthier, was described by Cotteau in 1893.[1] It is said to be eocene, but this needs confirmation.

Seeing that *Breynia carinata* is one of the most abundant and characteristic of the Gáj fossils and that its presence has been justly regarded as imparting a modern facies to the associated fauna, the discovery of a closely allied species in the Nari becomes a matter of considerable interest. I found specimens of this species in some Nari outcrops which I mapped in the year 1901 in the Pishin district of Balúchistán. These outcrops are of synclinal structure, resting unconformably either on eocene (Khirthar), or Triassic beds. They consist of white or yellow limestones largely built of corals and interbedded with shales or clays usually of a bright red colour. They are overlaid by the Siwaliks with varying amounts of structural unconformity, but always with a considerable stratigraphical break. Two of these outcrops have yielded the echinoid described in the present notice. One of them is situated at the eastern extremity of the Takatu range, the other in the neighbourhood of the village of Kudin (latitude 30° 37′, longitude 67° 35′), close to the boundary between the Pishin and Zhob districts. The latter exposure is in the immediate neighbourhood of the locality that yielded the specimens of *Halorites* and *Monotis* referred to by Professor Diener and by me in previous numbers of these *Records*.[2] The map illustrating my notice of these Triassic fossils gives the position of these Nari outcrops. At a short distance northwards and westwards there is a complete change of facies affecting not only the oligocene beds, but the underlying eocene strata also. Instead of a moderate thickness of white and brown Nari limestones and bright coloured clays, we find an enormous development of greenish sandstones and arenaceous shales, known as the Kojak beds, which include both the Nari and Gáj horizons, and represent the oligocene flysch. In the map just referred to, the area occupied by the Kojak shales, forming the greater part of the northwest portion of the map, instead of being coloured with the same tint as the eocene Ghazij, should have been grouped with the oligocene. The change of facies that has puzzled us so much until quite lately, is, as just mentioned, not restricted to the oligocene, but affects the

[1] Pal. Franç. Invert. Terrain tertiaire, Vol. II, Echinides Eocenes, p. 671.

[2] On the occurrence of a species of Halorites in the Trias of Balúchistán, *Rec. G. S. I.*, Vol. XXXI, p. 162 (1904). Notes on an Upper-Triassic Fauna from the Pishin District, Balúchistán, collected by E. Vredenburg in the year 1901, *Rec. G. S. I.*, Vol. XXXIV, p. 12 (1906).

eocene rocks as well. The Zhob and Pishin valleys correspond with the limit between two structural regions, the calcareous region to the south, and the flysch region to the north. This distinction was first recognised by Griesbach in 1881, for the region adjoining the Bolan Pass, Quetta, and Pishin, and the Kojak Pass.[1] It has since been found applicable to the whole of Balúchistán. For instance, the province of Sind belongs to the calcareous region, the adjoining province of Mekran to the flysch region.

Foraminifera are unfortunately lacking in the exposures that have yielded the interesting new species of *Breynia*. Nevertheless, the presence of several characteristic Nari fossils leaves no doubt as to their age. Amongst the fossils that belong exclusively to the Nari, the following have been identified: *Montlivaltia Vignei* d'A. and H., *Euspatangus rostratus* d'Arch.,[2] *Turritella Deshayesi* d'Arch., *Cerithium pseudocorrugatum* d'Orb. These strata contain an *Ostrea* very common in the true Nari of Sind and which closely resembles *Ostrea flabellula* Lam. It is represented in the Gáj by a closely related form which is perhaps specifically identical, but which grows to a much larger size, and for which Dr. Noetling has proposed the name of *Ostrea Blanfordiana* (Fauna of the Miocene beds of Burma, p. 110, *Pal. Ind.*, new ser., Vol. I, pt. 3, 1901). In the publications of the Geological Survey, it has often been erroneously referred to *Ostrea multicostata* Desh.[3]

[1] *Mem. G. S. I.*, Vol. XVIII, p. 4.

[2] I have pointed out in a previous notice that the supposed inclusion of this species in the Khirthar series (or indeed in the still older Laki, judging by the supposed associated fauna), according to Duncan and Sladen's monograph, is erroneous. (See page 189.)

[3] A curious confusion has taken place with respect to this Gáj fossil. Amongst the Sind fossils described by d'Archiac and Haime is an *Ostrea* which they looked upon as a variety of *Ostrea multicostata* Desh. (Description des Animaux fossiles du Groupe Nummulitique de l'Inde, p. 273, Pl. XXIV, fig. 14.) It is plentiful in the eocene of Sind (in the Khirthar or Laki, or both). There is a certain superficial resemblance between this species and the Gáj fossil related to *Ostrea flabellula* Lam. which, however, is distinguished by the great difference in size of its two valves and many other important points. Blanford and Fedden recognised that this is not the same form as Deshayes' *O. multicostata*, but referred it to d'Archiac and Haime's variety in spite of its divergence from the very exact figure of the monograph. In both editions of the Manual of the Geology of India, *O. multicostata* is quoted as one of the typical Gáj fossils, and an illustration purporting to represent it is published in the plate of the leading fossils of that stage (1st edition, Pl. XVI, 2nd edition, plate opposite p. 314. Here the confusion might have ended, had the fossil been figured from a genuine Gáj specimen. Instead of this, however, the figure is a copy of d'Archiac and Haime's illustration of the true eocene from which they regarded as *O. multicostata*, and one of the most typical eocene fossils of Sind does duty for a characteristic Gáj species.

Several more fossils have been identified which in Sind are restricted to the Nari, though their range may be different in other regions. These are a well characterised *Turbo*, probably undescribed, frequent in the Lower Nari of Sind; *Solarium affine* J. de C. Sow., only known in the Nari in western India, but regarded by Noetling as identical with the recent species *Solarium maximum* Philippi described as occurring in Burma in beds on the same horizon as the Gáj, or slightly newer (Fauna of the Miocene beds of Burma, p. 261), *Voluta jugosa* J. de C. Sow., *V. dentata* J. de C. Sow. the latter also occurring in Burma, according to Noetling in beds newer than the Nari (*op. cit.* p. 324).

There are a great many fossil species common to both the Nari and Gáj in Sind. Several of these have been identified amongst the specimens of the Balúchistán collection. They are *Pecten Bouei* d'Arch., *Venus granosa* J. de C. Sow., which my colleague Mr. Pilgrim considers identical with *V. Aglauræ* Brongn., a Castel-Gomberto fossil, *Turritella angulata* which resembles the recent *T bicarinata* Linn., *Turbinella affinis* J. de C. Sow. which is recorded by Fedden (*Mem. G. S. I.*, XVII, p. 207) as peculiar to the Gáj, but which I have found equally abundant in the Nari where it is represented by a somewhat smaller race which is the form met with in the Balúchistán exposures here referred to.

A few mollusca have also been identified which, so far, are only known in Sind as members of the Gáj fauna. These are *Pecten Favrei* d'Arch., *Trochus cognatus* J. de C. Sow. which closely resembles *T. lucasanus* Brong. of the oligocene of Castel-Gomberto, and a bivalve which seems undistinguishable from *Lucina columbella* Lam. which I have met with also at a low horizon of the Gáj in Sind.

The vertical distribution of most of the Gáj and Nari mollusca has not been accurately ascertained, and it is only certain fossils known for certain to occur only in the Nari, like those already mentioned, that can be relied upon, at present, for fixing the age of these beds. The evidence furnished by these characteristic forms is strengthened by the absence of all the important forms known to be exclusively characteristic of the Gáj, especially those which, like *Euspatangus patellaris* d'A. and H. and *Cerithium rude* J. de C. Sow., appear to represent corresponding species of the same genera in the Nari: these particular species never occur in the same bed with *Euspatangus rostratus* and *Cerithium pseudocorrugatum*.

These palæontological data are sufficient for fixing the age of these beds as Nari, but in the absence of foraminifera, it is not possible to decide whether they should be classed as Lower or Upper Nari. The presence of some mollusca which are known to occur in the Gáj might indicate that the beds are Upper Nari, but there are so many molluscan species common to the Nari and Gáj, and the zonal distribution of most of the mollusca has been so little studied, that very little reliance can be placed on these occurrences. We must content ourselves for the present with the conclusion that the beds are certainly Nari, without further fixing their exact zone.

DESCRIPTION.

The newly discovered *Breynia* is therefore certainly a Nari fossil and the oldest authentic representative of the genus hitherto referable to a well-established geological horizon. I propose to name it:

BREYNIA MULTITUBERCULATA.

1884. *Breynia carinata* Duncan and Sladen, Fossil Echinoidea of Western Sind, etc., *Pal. Ind.*, Ser. XIV, Vol. I, pt. 3, p. 229.

1907. *Breynia* spec. nov. Vredenburg, The Classification of the Tertiary System in Sind with reference to the Fossil Echinoidea described by Duncan and Sladen, p. 189, *Rec. Geol. Surv. Ind.*, Vol. XXXIV.

Definition.—*Breynia* of moderate to large size, of which the ambulacral petals are comparatively narrow, flexuous, and multiporous, while the paired interradia carry numerous large scrobiculated tubercles; the pores of the lateral ambulacra are distinctly developed within the internal fasciole; the apex is anteriorly excentric.

Description.—It may at once be mentioned that this echinoid so closely resembles the typical *Breynia carinata*, that there might be little objection to regard it as only a variety or "mutation" of that species. Nevertheless, the distinctive differences, although slight, are definite and constant, and as the occurrence of this form at a separate horizon makes it a good zone-fossil, it is advisable to name it separately. Of course, if the view be adopted that the distinctions are of no more than varietal value, the name here proposed may be interpreted as an abbreviation for *Breynia carinata* var. *multituberculata*.

The features that distinctly differentiate it from the typical *Breynia carinata* are the greater number of primary tubercles on the abactinal surface, and the characters of the ambulacral petals which are narrower, more flexuous, and with slightly more numerous pairs of pores than in *Breynia carinata*. In all these characters of the ambulacral petals, *Breynia carinata* is intermediate between the older *Breynia multituberculata* and the recent *Breynia Australasiæ*. In point of size, *Breynia multituberculata* is smaller than the typical *Breynia carinata*, but this is only when large series of specimens are taken into account, for the dimensions of both species vary considerably from one locality to another.

Apart from the differences just enumerated, the two species agree almost exactly in every other respect, and a detailed description of *Breynia carinata* would equally suit the older species. *Breynia carinata* has been described in such detail by Duncan and Sladen (Fossil Echinoidea of Western Sind, etc., p. 343, *Pal. Ind.*, Ser. XIV, Vol. I. 3) that a similarly minute description of the Nari form would be to a great extent a mere repetition. Reference may be made therefore to their work for those characters that are not specially dealt with in the following lines.

Specimens were obtained, as already stated from two localities: near Kudin at the eastern limit of the Pishin district, and at the eastern extremity of the Takatu range. The Kudin specimens are the larger ones. The following are the dimensions of several individuals from that locality :—

Dimensions in millimetres.

	Length.	Breadth.
Specimen No. 1	60	48
" " 2	65	52
" " 3	60	49
" " 4	70	55

The specimens from the Takatu are smaller and more variable in size most of them being immature.

Dimensions in millimetres.

	Length.	Breadth.
Specimen *a*	49	39
" *b*	45	36
" *c*	31	25

The ratio of length to breadth is more constant than in the specimens of *Breynia carinata* from Sind and agrees with the average of that form.

I have not given measurements of the thickness of any of these specimens because all are more or less crushed. The shape appears more depressed than that of *Breynia carinata,* but this may be a result of the vertical flattening which the tests have suffered. This deformation is least pronounced in the immature specimen *c* from the Takatu, the length and breadth of which are tabulated in the above list: the greatest height of the test situated at about the apex or close behind it is 10·5 millimetres.

The ratio of height to length and breadth is therefore about the same in this specimen as in the average of *Breynia carinata,* and although it must be kept in mind that young echinoids have a tendency to be more globose than the adult forms, this does not seem to be the case with *Breynia carinata* judging from the dimensions of immature specimens tabulated by Duncan and Sladen.

Apart from the doubtful longitudinal profile, the outline of the test is just the same as in *Breynia carinata,* and agrees in every point with the extremely detailed description of Duncan and Sladen.

None of the specimens show the same continuous convexity of the abactinal surface as *Breynia carinata,* the ridges on either side of the anterior sulcus, in particular, being more marked, but just as in the case of the flattened outline, these characters cannot be relied upon owing to the crushed condition of the tests. In a great many specimens the flattening of the test has not affected the marginal outline which is practically identical with that of *Breynia carinata* as may be ascertained by a comparison with the detailed survey of this feature given in Duncan and Sladen's description. Just as in the Gáj species, this outline is heart-shaped, somewhat rostrate posteriorly, anteriorly notched by the anterior sulcus, the greatest breadth being about on a level with the anteriorly excentric apex. There is the same number of tumid angular swellings along the margin as in *Breynia carinata,* three on either side, the first one situated in the anterior inter-ambulacrum, near the junction of the two rows of plates, the second one in the lateral inter-ambulacrum at about the level of the apex and of the greatest breadth of the test, the third one further back, at the commencement of the posterior rostration. As in *Breynia carinata,* they occupy the centres of concentric rows of tubercles on the actinal surface.

The anteriorly excentric apex, the much more anterior peristome, the periproct situated high up the posterior margin, but overhung by the upper part of the posterior rostration, all occupy the same relative positions as in *Breynia carinata.* Owing to their crushed condition, none of the specimens show clearly the details of the periproct, but the apex and peristome are clearly exhibited in several examples.

The apical disk is small and compact. The genital pores are situated close together, the posterior ones being slightly larger than the anterior ones. The posterior pair are separated by the madreporite which is lanceolar in shape, and extends backwards into the posterior inter-ambulacrum. In all its characters, the apical disk agrees exactly with that of *Breynia carinata.*

The anterior ambulacrum has small pores relatively crowded towards the apex, and gradually further apart towards the margin and from there to the peristome. It is identical in every detail with that of *Breynia carinata.*

The petaloid portions of the paired ambulacra differ from the corresponding organs of *Breynia carinata* in shape and, to a slight extent, in the number of pairs of pores, as has already been mentioned. They are narrower than in *Breynia carinata*, the width of the interporiferous zones being greatly reduced thereby. At the same time they are more flexuous, and scarcely suggest the rigid triangular shape which they nearly approach in *Breynia carinata* and which culminates in *Breynia Australasiæ.* It is the anterior poriferous zones of both lateral pairs of ambulacra that best show this flexuosity, the corresponding zones in *Breynia carinata* being almost straight.

As a consequence of the comparative narrowness of the petals, the anterior poriferous zones of the anterior petals tend to converge towards one another at an appreciable angle instead of being disposed along one transverse straight line as in *Breynia carinata.*

In the petaloid part of the poriferous zones, the pores are large, each pair being situated in a deep furrow separated from that of the next pair by a granulated ridge. These details are identical with those observed in *Breynia carinata,* but the total number of pairs in the petaloid portions is slightly greater in *Breynia multituberculata.* In this respect, *Breynia carinata* is intermediate between the Nari species and the recent Pacific form as is shown by the figures of the following list, to which have been appended the corresponding numbers observed on a specimen of an undescribed recent species that inhabits the Indian Ocean:[1]

	Ia	Ib	IIa	II	IVa	IVb	Va	Vb
Breynia Australasiæ Leach . . .	13	16	15	10	9	15	14	13
Breynia carinata d'Arch. *a* . .	17	19	15	12	12	16	19	17
" " " *b* . .	17	19	14	12	11	15	20	18
" " " *c* . .	...	...	...	...	10	13	14	14
" " " *d* . .	18	19	14	12	...	...	18	18
" " " *e* . .	...	...	17	14	14	17	21	20
" " " *f* . .	18	18	14	11	11	16	18	18
Breynia multituberculata n. sp. 1 . .	18	21	16	14	14	16	21	18
" " " 3 . .	18	22	...	...	...	...	21	17
" " " 4 . .	18	17	...	...	12	15	19	19
" " " 5 . .	...	...	...	...	10	14	20	...
" " " 6 . .	17	20	...	...	...	...	...	...
" " " 7 . .	...	...	...	...	13	15	...	...
" " " 8 . .	...	21	...	...	...	...	...	...
" " " 9 . .	...	...	...	...	14	17	19	18
" " " *c* . .	16	...	...	...	...	...	16	17
Breynia n. sp.	14	16	13	9	...	...	17	14

The numbers for *Breynia Australasiæ* were counted on the photograph representing this species in the Revision of the Echini by Al. Agassiz (Pl. XV*a*, fig. 7[2]). The specimens of *Breynia carinata* indicated by the letters *a*, *b*, *c*, are those represented respectively

[1] A description of this species by Major A. R. S. Anderson will shortly appear in the Journal of the Asiatic Society of Bengal.

[2] This specimen is about the size of the average full-grown specimens from Sind. In Pl. XLI of Loven's Etudes, the number of pairs of pores for the petaloid part of the ambulacra is greater. The figure has perhaps been drawn from a larger specimen as this species grows to a much larger size.

in figs. 5, 8, 6, Pl. LIV of Duncan and Sladen's monograph on the fossils Echinoidea from Sind. The specimens *d* and *e* are those illustrated respectively by the figures 1 and 3, Pl. X, of the description of the fossil Echinoidea of Kachh and Kathiawar by the same authors, the second specimen being a very large individual. The specimen *f* is from the province of Jhalawan in the State of Kelat and belongs to a smaller race than the Sind examples. Of *Breynia multituberculata*, the specimens 1, 3, 4, *c* are those of which the dimensions were given in a previous paragraph. The remainder are incomplete specimens from Kudin, all full-grown. Specimens 5 and 9, when complete, must have been of about the same size as the rather large specimen 4. The small number of pores in the anterior zone of the anterior petal of No. 5 is caused by an angular expansion of the internal fasciole, an individual character also observed in many specimens of *Breynia carinata.* The other specimens from Kudin are of about the same size as specimen No. 1. The recent specimen from the Bay of Bengal, which belongs to the Indian Museum, is of small size, only about 40 millimetres in length. It is interesting, therefore, to notice that the pores of its petals are rather numerous, the species being in many characters closely related to the Gáj and Nari forms. The small number in the anterior zone of the anterior petals is due to the obliteration of 3 or 4 pairs outside the internal fasciole, as in the case of *Breynia Australasiæ.* I owe to the kind courtesy of Dr. Annandale, Officiating Superintendent of the Indian Museum, the favour of having been able to examine this interesting Indian recent species.

Taking the average of the figures tabulated above, we find that in adult specimens the mean number of pores for the various zones of the petals is as follows :—

	ANTERIOR PETALS.		POSTERIOR PETALS.	
	Anterior zones.	Posterior zones.	Anterior zones.	Posterior zones.
Breynia Australasiæ . .	9 to 10	15	15	13
" *carinata* . . .	12	15	18	17
" *multituberculata* . .	12 to 13	15 to 16	20	18

In the case of *Breynia Meslei*, Cotteau gives 7-8 pairs for the anterior zones and 10-11 pairs for the posterior zones in the anterior petals, 14-15 in the anterior zones and 12-13 in the posterior zones of the posterior petals. But, owing to the small dimensions of the specimens, these numbers, like those of the recent Indian species, cannot be conveniently compared with those of the three species tabulated above.

There is not such a marked obliteration of the pores of the lateral ambulacra within the internal fasciole as in the case of *Breynia Australasiæ*: in the latter species, several pairs of pores are obliterated even outside the internal fasciole in the part of the poriferous zones adjacent to it. In the Nari form, small pairs of pores continue up to the apical disk just as in *Breynia carinata*. But it is only rarely that the posterior zones of the anterior pair, and anterior zones of the posterior ones exhibit within the internal fasciole a few pairs of pores with the same structure as those outside it, such as is nearly always the case with *Breynia carinata*, and is occasionally observed to a slight extent even with *Breynia Australasiæ*, at least with regard to the antero-lateral ambulacra. Duncan and Sladen's statement with regard to the antero-lateral ambulacra of *Breynia carinata*, to the effect that "the posterior poriferous zone within the fasciole has almost invariably, but not universally, three or four pairs of pores which are similar to those beyond the fasciole"[1] can be exactly reversed in the case of *Breynia multituberculata*. Out of twelve specimens from Kudin in which the apical portion of the test is preserved, there are only three in which this feature is developed. In these few instances, however, the structure is just the same as in the normal specimens of *Breynia carinata*.

The peristome closely corresponds with that of *Breynia carinata*. The peripodial processes, however, are more excavated, and the spheridial pits much deeper.

Duncan and Sladen have noticed (Fossil Echinoidea of Sind, p. 353, and fig. 5, Pl. LV) that in the peristome of *Breynia carinata*, the paired interradia are not excluded from the peristomial margin, a feature exhibited by *Breynia Australasiæ*, and unique, so far as known, amongst the *Spatangidæ* (Loven's "Etudes,"[2] Pl. XLI). *Breynia multituberculata* and the recent Indian species agree in this respect with *Breynia carinata*, and the distribution of the plates in

[1] Fossil Echinoidea of Western Sind, p. 348.
[2] *Kongl. Svensk. Vetensk-Akad. Handl.*, new series, Vol. XI, pt. 7, (1874).

the immediate neighbourhood of the peristome in all three species, somewhat resembles that illustrated by Loven for *Kleinia luzonica* Gray: ("Etudes," Pl. XXXVIII), *Echinocardium cordatum* Penn. (Pl. XXXIX), *Lovenia subcarinata* Gray (Pl. XLIII). In this respect, therefore, the Indian forms, both fossil and recent, have not reached the same degree of differentiation as *Breynia Australasiæ*. On the other hand, in both Indian fossil species, the odd interradium exhibits a curiously exceptional peculiarity: the plates I*a*3 and V*b*3 of the posterior ambulacra come into contact with one another, entirely disconnecting the labrum from the sternum. Thus the odd interradium is severed in a manner which has not been observed in any other spatangid that I am aware of, and which slightly recalls the extraordinary displacements of various series of plates that have been observed amongst the *Pourtalesiidæ*.

This exceptional constitution of the odd interradium is largely due to the small size of the sternum in both the fossil species, a character which they share with the recent Indian form. It is also to adjust themselves to its reduced dimensions that the broad posterior ambulacra follow such a remarkably rectilinear course on the actinal surface in the fossil and recent Indian species. In *Breynia Australasiæ*, the relatively large sternum and the curved shape of the posterior ambulacra surrounding it, give to the actinal surface a somewhat more archaic appearance than that of the two oligocene species and their modern Indian successor. In the recent specimen shown to me by Dr. Annandale, the labrum has the same elongated shape as in the Gáj and Nari forms, but is not entirely separated from the sternum. The specimen seems immature, and it is only in adult specimens of the fossil forms that the separation becomes complete.

The large scrobiculated tubercles between the internal and peripetalous fascioles in the paired interradia are more numerous and more crowded than those of *Breynia carinata*, and consequently somewhat smaller. It is their number and disposition that constitute the most conspicuous difference in their general appearance between the Nari and Gáj species. In *Breynia multituberculata* the scrobicules of these large primary dorsal tubercles are so closely crowded as to be usually separated by a mere ridge, while in *Breynia carinata* broad granulated spaces intervene, at least between the successive rows of large scrobicules.

These large scrobicules are not nearly so deep as in *Breynia carinata*. The large tubercles which they circumscribe resemble the corresponding ones of *Breynia carinata,* but owing to the shallowness of the scrobicules, they rise rather more over the general level of the test than in the case of the Gáj species. As in the latter species, it is only the anterior part of the collar surrounding the perforated mamelon that is crenulated.

There are about nineteen to twenty-three of these large tubercles in each of the anterior interradia, and twenty-seven to thirty-three in each of the lateral ones, the corresponding numbers in the case of *Breynia carinata* being respectively thirteen to fifteen, and twenty to twenty-four.

In *Breynia carinata,* the large tubercles in each of the paired interradia are arranged in four concentric zones, the outer row containing the greatest number while the one nearest the apex seldom consists of more than two and is often reduced to a single one, this being generally the case in the anterior ambulacrum. In *Breynia multituberculata* the number of rows is five instead of four. The series are especially distinct in the posterior ambulacra where the average numbers of tubercles in successive rows, taking them in the order from the margin to the apex, is amongst adult specimens of 60 to 70 millimetres in length: 5+11+7+4+2=29. The third and fourth row have a peculiar wavy shape somewhat like that of a very extended letter M. The outermost row of five tubercles does not extend right across the interradium, but is restricted to its posterior zone, being situated on plates 1 *a* 7 and 4 *b* 7, the same plates carrying also the posterior tubercles of the fourth row.

This fifth row in *Breynia multituberculata* is homologous with the posterior half of the fourth row in *Breynia carinata*: in other words, the additional tubercles missing in *Breynia carinata* are those normally constituting the posterior part of the fourth row in *Breynia multituberculata,* and it is the combination of the anterior remnant of the fourth row together with the original fifth row that constitute together the fourth row of the Gáj species.

In the anterior interradia of *Breynia multituberculata,* the large tubercles are disposed along four or five zones, but the disposition in series is not so well defined as in the lateral interradia. In the left anterior interradium of the specimen represented in fig. 1 where the successive series are fairly distinct, the respective numbers taken in succession from the margin towards the apex are 2+6+7+3+1=19.

The homologies of the ornamentation in the Gáj and Nari forms can be ascertained by comparing the distribution of the tubercles in the two species: in *Breynia multituberculata* the tubercles constituting the fourth row may be all approximately of the same size, or if their dimensions differ appreciably, these different-sized tubercles are not distributed according to any regular law. The five tubercles usually constituting the short fifth row decrease regularly in size in a forward direction, and the same feature is observed in the four or five tubercles constituting the posterior part of the fourth row in *Breynia carinata*, which are disposed exactly like the true fifth row of *Breynia multituberculata*. The last tubercle of this gradually decreasing series is very small and is immediately succeeded in the Gáj species by a normal-sized tubercle which is homologous with one of the true fourth row in *Breynia multituberculata*. The crowded condition of the tubercles in *Breynia multituberculata* and their comparatively wider spacing in *Breynia carinata* does not affect the similarity of disposition of the outer row in the two species, which further tends to confirm this homology.

In both species these particular tubercles are situated on plates 1 *a* 7 and 4 *b* 7, these plates also carrying the additional posterior tubercles of the fourth zone in *Breynia multituberculata*. These are the only plates carrying portions of more than one zone of large tubercles. Thus, in the left lateral interradium, the anterior part of the fourth zone is situated on 1 *b* 6, the third row on 1 *a* 8-*b* 7, the second on 1 *a* 9-*b* 8, while in full-grown specimens one or both of the plates 1 *a* 10, 1 *b* 9, may carry a primary tubercle.

In immature specimens of *Breynia multituberculata* the number of tubercles is much less. In the small specimen from the Takatu represented on Plate XXXIX, the left posterior interradium carries only eight large tubercles disposed in the order 5+2+1. Usually the more actinal zones of large tubercles are those first developed, as is shown by their distribution on immature specimens; but the fourth zone of *Breynia multituberculata* is completed before the fifth one is developed.

The peculiar distribution of the tubercles in the lateral ambulacra which characterises *Breynia multituberculata* is well exhibited in the crushed test erroneously included in Blanford and Fedden's Khirthar collection and identified as *Breynia carinata* by Duncan and Sladen who noticed that it cannot belong to the same horizon as the remainder of the collection with which it has been associated (Fossil Echinoidea of Western Sind, p. 229). It was probably obtained in the Nari limestone which rests directly on the Khirthar limestone at the place where the specimen was collected.

The ornamentation of the lateral and anterior portions of the actinal surface is similar to that of *Breynia carinata*, though slightly sparser, another point in which *Breynia carinata* is intermediate between the recent *Breynia Australasiæ* and the Nari form. This ornamentation consists of numerous tubercles radiating from the marginal angular swellings mentioned in a previous paragraph. As in the Gáj species, their size and spacing increases with their distance from the margin, and they are similarly perforated, crenulated only on the posterior side, and excentrically situated in flat slightly raised scrobicules, here and there separated from one another by a few granules. This ornamentation ceases at the outer edge of the posterior ambulacra.

The three fascioles are very distinct, and are identical with those of *Breynia carinata*. The peripetalous fasciole is narrow, follows a rounded course and circumscribes the area occupied by the large abactinal tubercles. The internal fasciole encloses a somewhat rectangular space. It is also narrow, and frequently separates anteriorly in two branches, as is often the case with all the species that exhibit this particular fasciole. The straightness of its course is sometimes interfered with by outward lateral angular expansions towards the poriferous zones of the anterior petals, just as in certain specimens of *Breynia carinata*.

The subanal fasciole is broad and encloses a broad heart-shaped plastron. The posterior extremity of the test is damaged in all the available specimens, so that none of them show completely the details of this plastron. All that can be seen agrees with the corresponding portions of *Breynia carinata* which, moreover, does not seem to differ appreciably in this respect from *Breynia Australasiæ*. In the latter species the space enclosed by the subanal fasciole is comparatively a trifle broader in consequence of the broader outline of the corresponding part of the test.

Relation to other species.—The three Indian species of *Breynia* constitute a group of closely allied forms. The character of the dorsal primary tuberculation, crowded in *Breynia multituberculata*, wider-spaced in *Breynia carinata*, almost obsolete in the recent species, constitutes the most obvious distinction between them. The Nari form is also distinguished from the Gáj one by its narrower petals; the recent species resembles the Nari more than the Gáj species in this respect, but differs from them both in the obliteration of some pores outside the internal fasciole. In the fossil species from India and Africa, the obliteration of the pores of the lateral ambulacra within the internal fasciole is not so pronounced as in the two recent forms.

In the latter character, the recent Indian species agrees with the recent Pacific one which, however, differs considerably from all the Indian forms by its almost central apex, its large sternum surrounded by curved ambulacra, and the exclusion of the paired interradia from the peristome.

There is not such a marked contrast between the primary and secondary tuberculation of the dorsal surface in *Breynia Australasiæ* as in the Indian species. This is perhaps the case also with *Breynia Meslei* so far as can be made out from the figures in the Paléontologie Française, and it agrees also with *Breynia Australasiæ* in its almost central apex. The actinal surface, owing to the straight course of the posterior ambulacra is more like that of the three Indian species than of the Pacific one, at least so far as can be made out from fig. 3, Pl. 363, of the Paléontologie Française. But the African species differs from other fossil and recent ones by the structure of the posterior portion of the test which is not rostrated and lacks the overhanging prolongation of the dorsal surface, so that the periproct is visible from above.

Breynia magna Herklots[1] from Java which has been described as miocene but is more probably oligocene, was compared by Martin to *Breynia Australasiæ*[2] previous to Duncan and Sladen's careful description of *Breynia carinata*, its identity with the latter species as figured by Medlicott and Blanford (Manual, Geol. Ind., 1st ed., Vol. XVI, fig. 9) being also suggested. The fragment figured by Herklots though very incomplete is so well characterised, that it is quite sufficient to settle its specific identity with *Breynia carinata*.

Duncan and Sladen have mentioned the supposed occurrence of a *Breynia* from the island of Henjam in the Persian Gulf,[3] which was obtained in beds that were then considered to be pliocene, but which

[1] Fossiles de Java, IVeme partie, Echinodermes, p. 13, Pl. II, fig. 7 (1854).

[2] Die Tertiärschichten auf Java, Appendix, p. 5 (1880).

[3] A description of the fossil Echinoidea of the coast of Balúchistán and of some islands in the Persian Gulf, p. 381 (1886), *Pal. Ind.*, Ser. XIV, Vol. I, pt. 3.

probably correspond with the Hingláj series of Balúchistán which does not contain any strata newer than middle miocene. Duncan and Sladen abstained from naming this species owing to the incomplete condition of their specimen. It was referred to the genus *Breynia* in spite of the absence of a peripetalous fasciole. Their type has now been almost entirely destroyed. All that remains is a small fragment of the marginal portion of the left anterior interradium, with only one primary tubercle preserved on what little subsists of the adjoining abactinal surface, and no trace of a peripetalous fasciole. The small portion still preserved of the actinal surface shows tubercles surrounded by the deeply excavated scrobicules that characterise *Lovenia* and are quite different therefore from the slightly raised imbricated actinal scrobicules of *Breynia*. These characters, together with the absence of a peripetalous fasciole suffice to show that the specimen is a *Lovenia* and not a *Breynia*.

A comparison with *Breynia cubensis* Cotteau is impracticable owing to the unsatisfactory state of preservation of the type, Cotteau himself having expressed doubts regarding its generic attribution and also its supposed eocene age.[1]

As to *Breynia sulcata* d'A. and H., I cannot trace any other description besides the short notice in the "group nummulitique de l'Inde," p. 216. The diagnosis is too condensed to furnish points for detailed comparison.[2]

Apart from this species there remain therefore five well established species of *Breynia*: *Breynia Australasiæ* Leach, *Breynia carinata* d'A. and H., *Breynia Meslei* Gauthier, *Breynia* n. sp. from the Indian Ocean, and the present species *Breynia multituberculata*. The main characteristic differences between these five species may be tabulated as follows:—

[1] *Ann. Soc. Geol. Belg.*, Vol. IX (1881-1882), p. 45. The fossil echinoid fauna of Cuba has been revised by Egozcue y Cia (Bol. Com geol. espan. XXII, 1897), but I cannot obtain access to this work.

[2] In a foot-note of the "Revision of the Genera," (p. 265), Duncan mentions *Breynia sulcata* and also quotes a mention of it by Pomel, but without giving any reference for either statement. The species is there attributed to Haime alone.

	Breynia multituberculata.	*Breynia carinata.*	*Breynia* n. sp. from the Indian Ocean.	*Breynia Australasiæ.*	*Breynia Meslei.*
Relative size .	Medium to large .	Medium to very large	Medium (perhaps immature).	Large to very large .	Medium.
Position of apex .	Anteriorly excentric	Anteriorly excentric .	Anteriorly excentric .	Subcentral . . .	Subcentral.
Structure of peristome.	All the interradia entering the peristome.	All the interradia entering the peristome.	All the interradia entering the peristome.	Paired interradia excluded from the peristome.	?
Shape of posterior ambulacra actinally.	Straight . .	Straight . . .	Straight . . .	Curved . . .	Straight.
Abactinal tuberculation.	Large primary tubercles very numerous with contiguous scrobicules.	Large primary tubercles numerous and disposed in rows; the scrobicules of successive rows separated by granulated spaces.	Only one or two primary tubercles in each anterior interradium; primary tuberculation obsolete in the other interradia.	Numerous primary scrobiculated tubercles; the difference in size between the primary and secondary tuberculation not so pronounced as in the three Indian species.	Numerous primary scrobiculated tubercles, the difference in size between the primary and secondary tuberculation not so pronounced as in the three Indian species.
Characters of posterior extremity of test.	Rostrated; dorsal prolongation overhanging periproct.	Rostrated; dorsal prolongation overhanging periproct.	Rostrated; dorsal prolongation overhanging periproct.	Rostration somewhat broad and blunt as compared with the three Indian species; dorsal prolongation overhanging periproct.	Not rostrated; periproct visible from above.
Structure of paired ambulacra within internal fasciole.	Small pores present; occasionally a few pores contiguous to the fasciole similar to those outside it.	Small pores present; usually a few pores contiguous to the fasciole similar to those outside it.	Pores within the fasciole very minute.	Pores within the fasciole mostly obsolete.	Small pores present.
Characters of petals	Comparatively narrow and flexuous.	Comparatively broad, nearly straight.	Comparatively narrow and flexuous; some pores obliterated in anterior zone of anterior pair outside the internal fasciole.	Broad and triangular; some pores obliterated in anterior zones of anterior pair outside the internal fasciole.	Comparatively narrow with curved outlines.

The close relationship between the fossil and recent Indian species, indicating the persistence of a particular type in the Indian region since such a remote period as the oligocene, is a fact of considerable interest. If supported by similar evidence amongst other marine genera it would indicate a very ancient origin for some of the modern regional faunas.

EXPLANATION OF PLATE 38.

1.—*Breynia multituberculata.*—Specimen from Kudin, abactinal view, natural size.

1*a*.—Internal fasciole of the same specimen, enlarged.

2.—Actinal view of another specimen from the same locality, natural size.

3.—Immature specimen from the Takatu range. Abactinal view, natural size.

3*a*.—Longitudinal profile of the same specimen.

3*b*.—Actinal view of the same specimen.

4.—Distribution of primary tubercles in posterior lateral interradium of a specimen of *Breynia carinata* for comparison.

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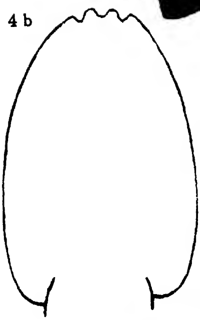
G. I. C. P. O.—No. 68 D. G. S.—11-3-1907.

Collotype Max Jaffé,

Fossils from the Halorites limestone.

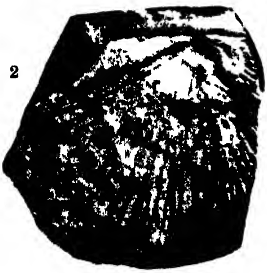
1

4 b



4 a

2



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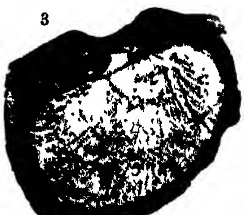
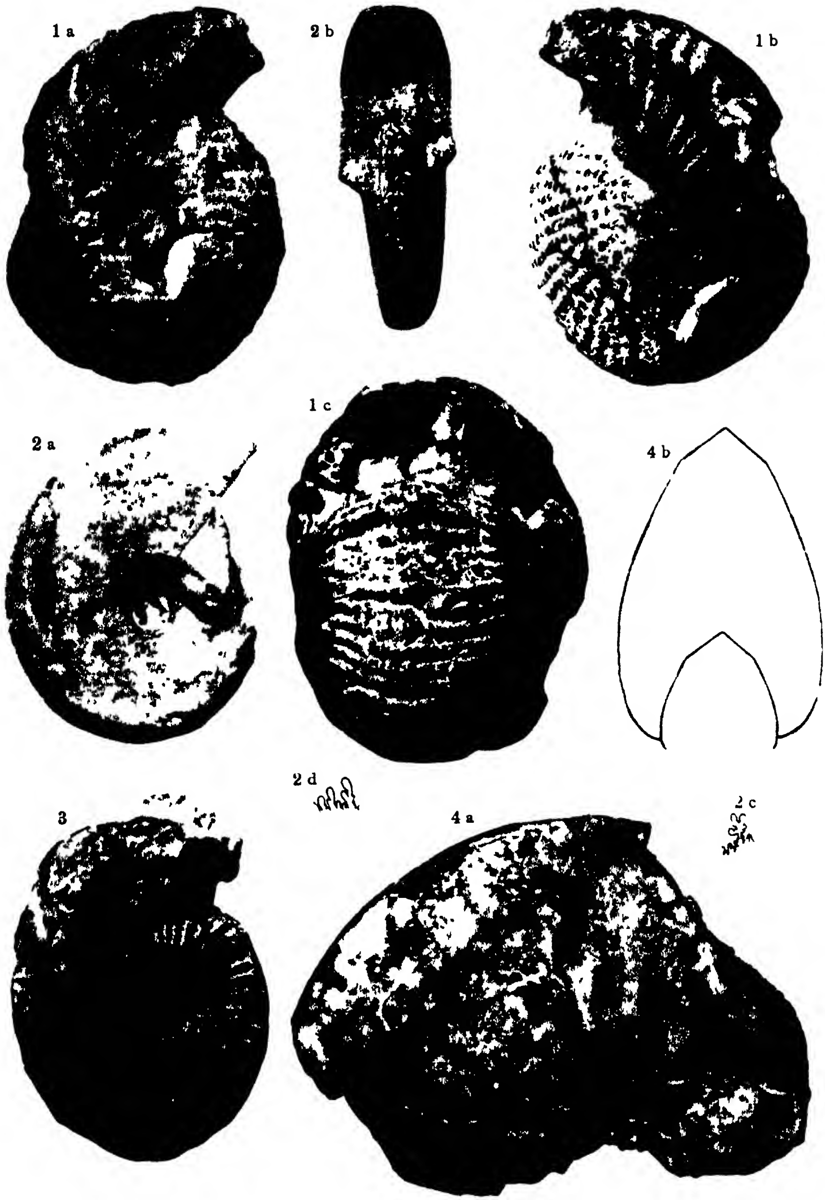


Collotype Max Jaffé

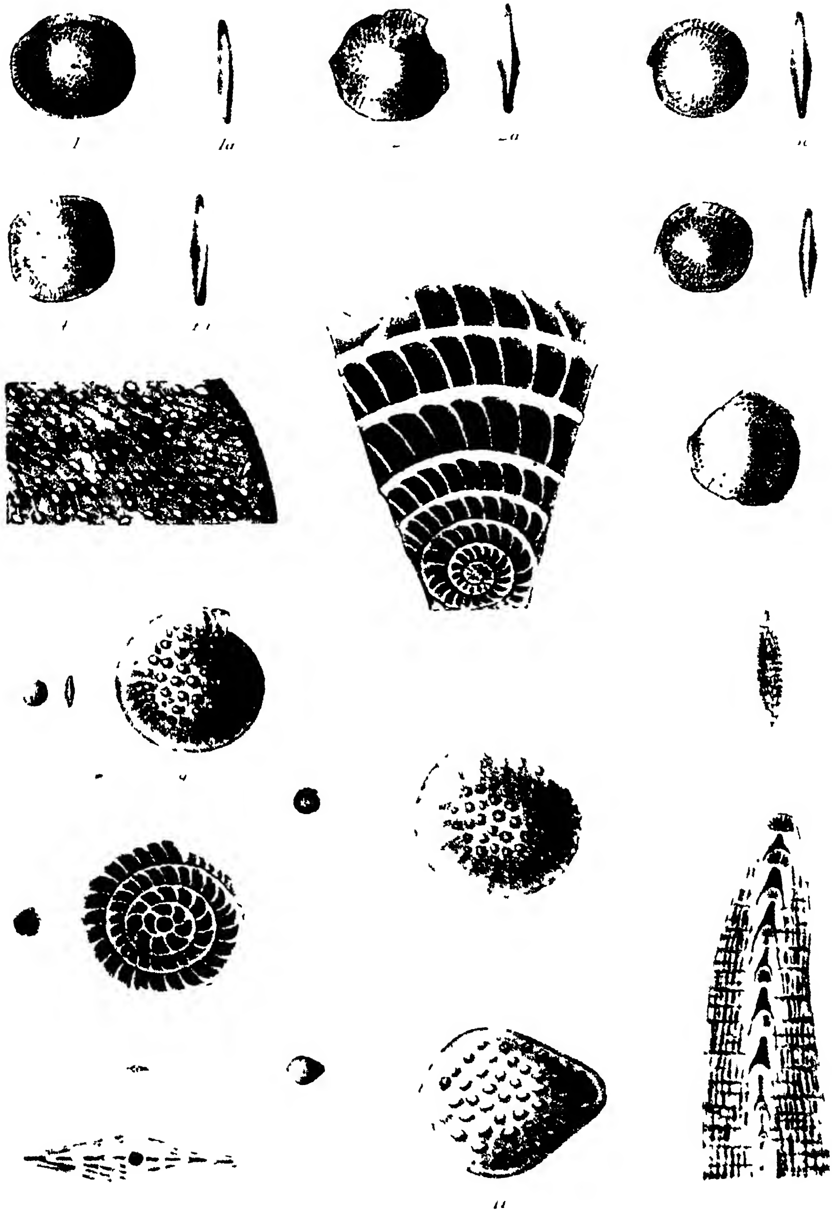


Collotype Max Jaffe, Vienna

Triassic Fossils from the Pishin district, Balúchistán.

E. Vredenburg.

Records, Vol. XXXIV, Pl 8.

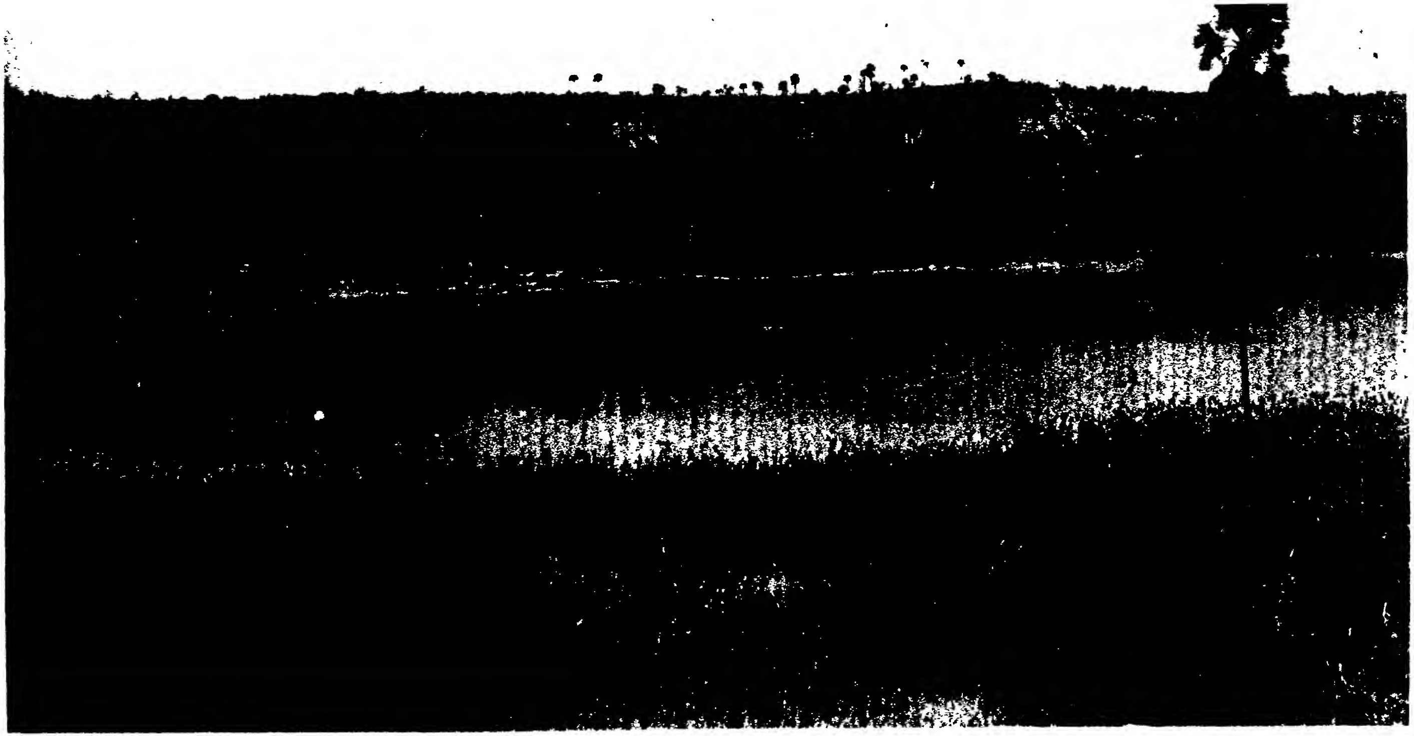


Nummulites Douvillei n. sp.

J. M. Maclaren

J. M. Maclaren, Photo. *Bemrose, Collo., Derby, Eng.*

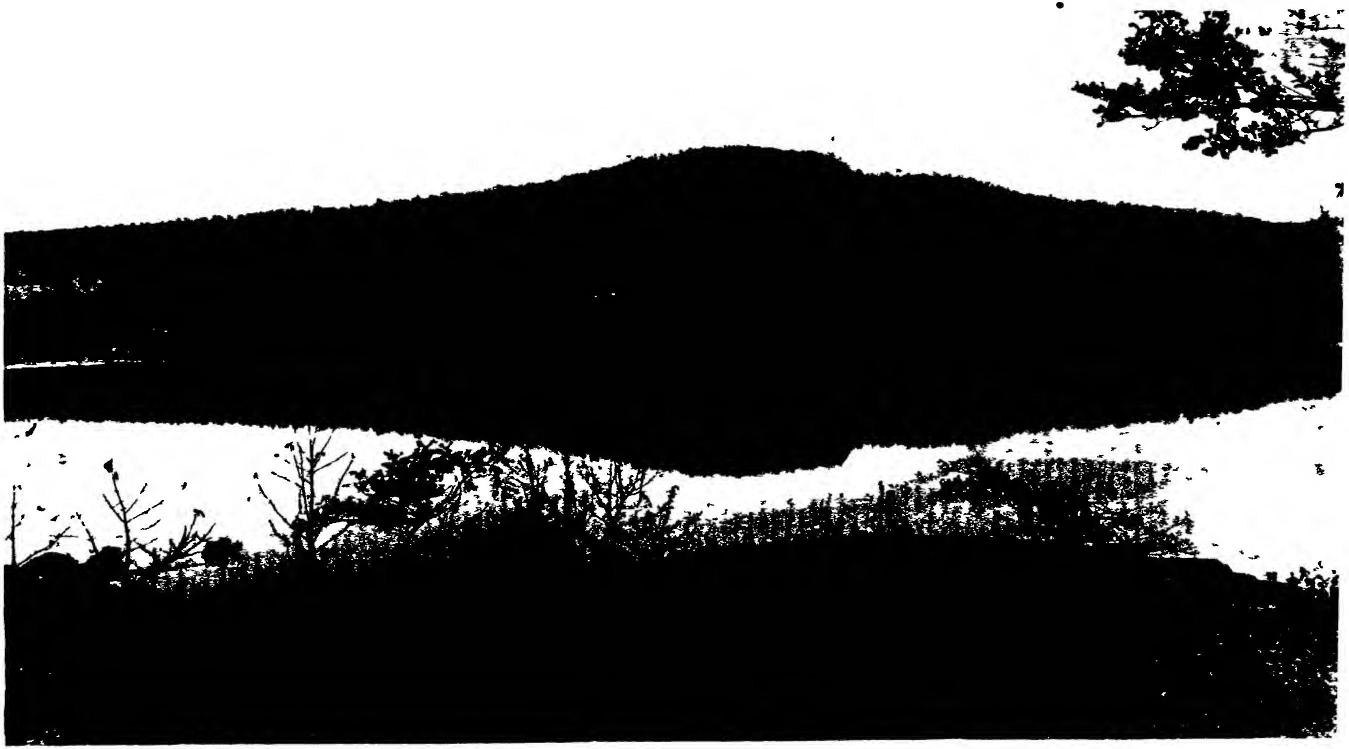
ANCIENT ROCK MORTARS, NAGAVI VILLAGE, GADAG.



Photographed by F. D. Oldham

Bemrose, Collo., Derby.

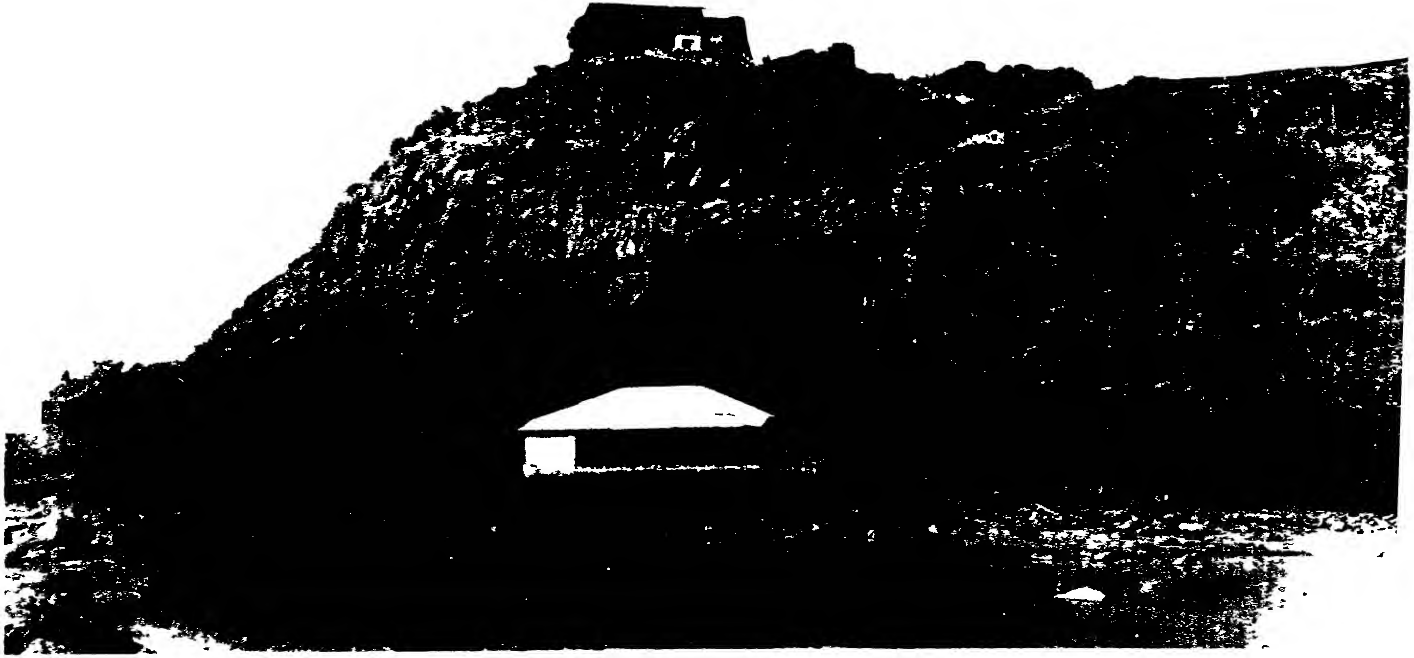
THE LESHE CRATER, SHOWING BEDDED ASHES OVERLYING PLIOCENE SANDSTONE IN THE CRATER WALL.



by R. D. Oldham

CRATER LAKE OF TWIN TRUNCATED TUFF CONE IN BACKGROUND

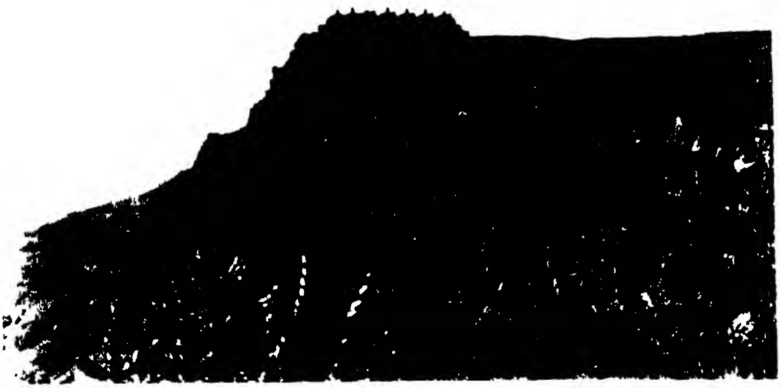
PÁVÁGAD HILL, WITH THE RUINED MUSALMAN CITY OF CHAMPANER IN THE FOREGROUND. TAKEN



Photograph by L. L. Fermor

THE SUMMIT OF PAVAGAD HILL

FIG. 1 THE SUMMIT LAVA-FLOWS OF PÁVAGAD HILL FROM N OF E WITH THE MAULIYA PLATEAU IN THE FOREGROUND



Photographed by L. L. Fermor.

FIG. 2 THE NAV LÁKH KOTHÁRS ON A PLATEAU OF HORIZONTALLY-BEDDED LAVAS ON PAVAGAD HILL

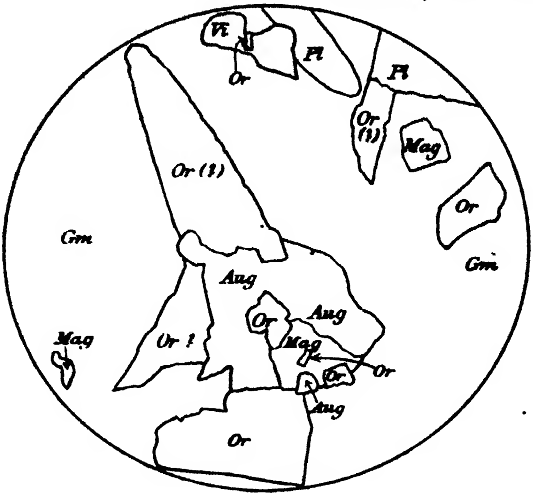


Fig. 1—No. 4 (See p. 154)—18·95—5222—Ordinary light— x 20.

Pitchstone.

Aug = Augite; Gm = Glassy ground-mass; Mag = Magnetite; Or = Orthoclase; Pl = Plagioclase; Vi = Viridite pseudomorphous after Augite.

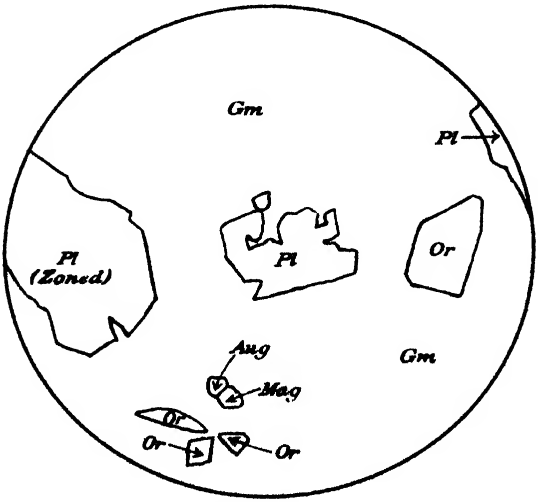


Fig. 2.

Same rock as Fig. 1. Shows felspar corroded by the ground-mass.

FIG. 1

FIG. 2

Photo-micro. by L. L. Fermor.

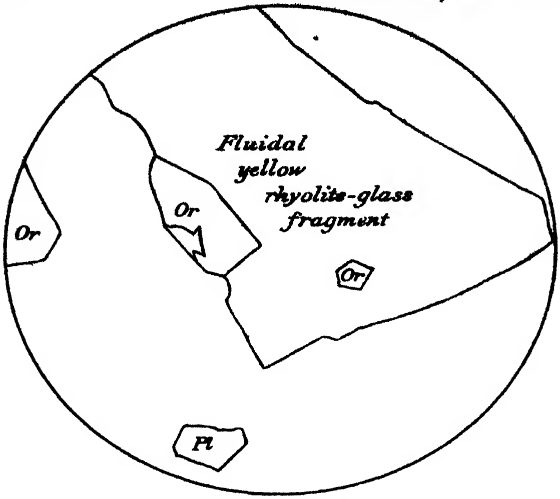


Fig. 1—No. 9 (See p. 158)—18·100—5227—Ordinary light— × 20.

Silicified Rhyolite-breccia.

Consists of angular fragments of rhyolite-glass (dark) in a ground-mass of quartz mosaic (light), except :—
Or = Orthoclase ; Pl = Plagioclase.

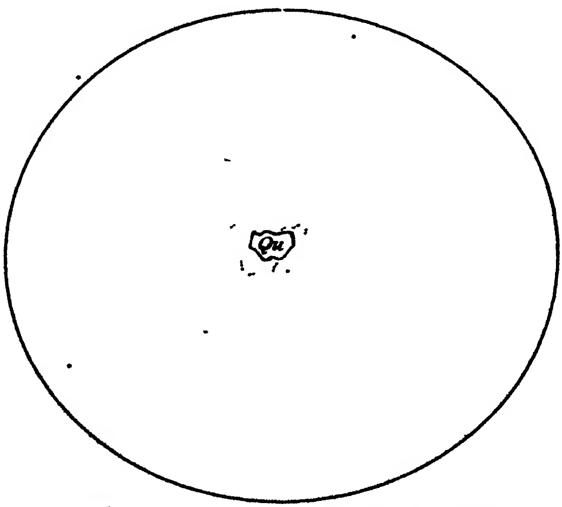


Fig. 2—No. 5 (See p. 155)—18·97—5224—Nicols crossed — × 27.

Rhyolite.

The central quartz phenocryst (Qu) has quartz of ground-mass in optical continuity over area included by dotted lines.

L. L. Fermor. Records, Vol. XXXIV, Pl. 22

Fig 1

Photomicrographs by L. L. Fermor.

Fig 2

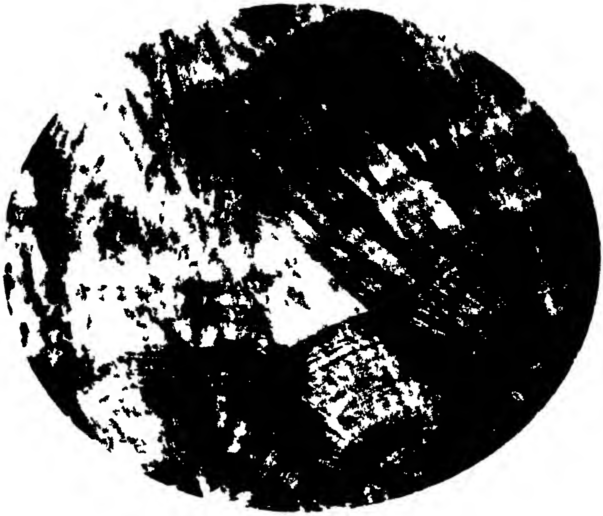
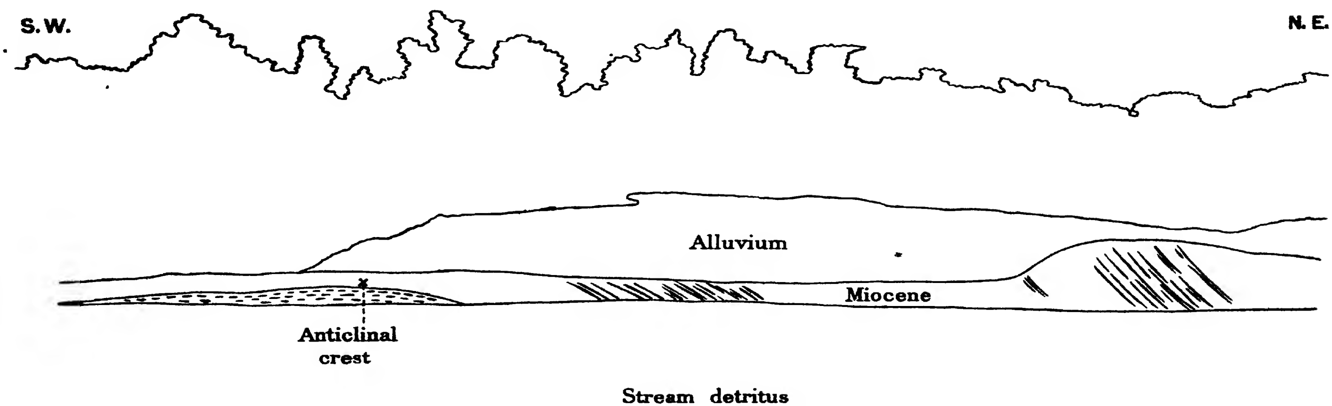


FIG 1.—J 875 5701—ORDINARY LIGHT— 38
RADIATE FIBROUS GIBBSITE FROM TALEVADI

FIG 2.—J 875 5701 ORDINARY LIGHT—×38
MANGANESE-ORE (BLACK) AND GIBBSITE (WHITE) FROM TALEVADI

E. H. Pascoe, Photo *Bemrose, Collo, Derby*



SECTION IN THE CHAUNG MA, SHEWING THE CREST AND EASTERN SLOPE OF THE KABAT ANTICLINE.

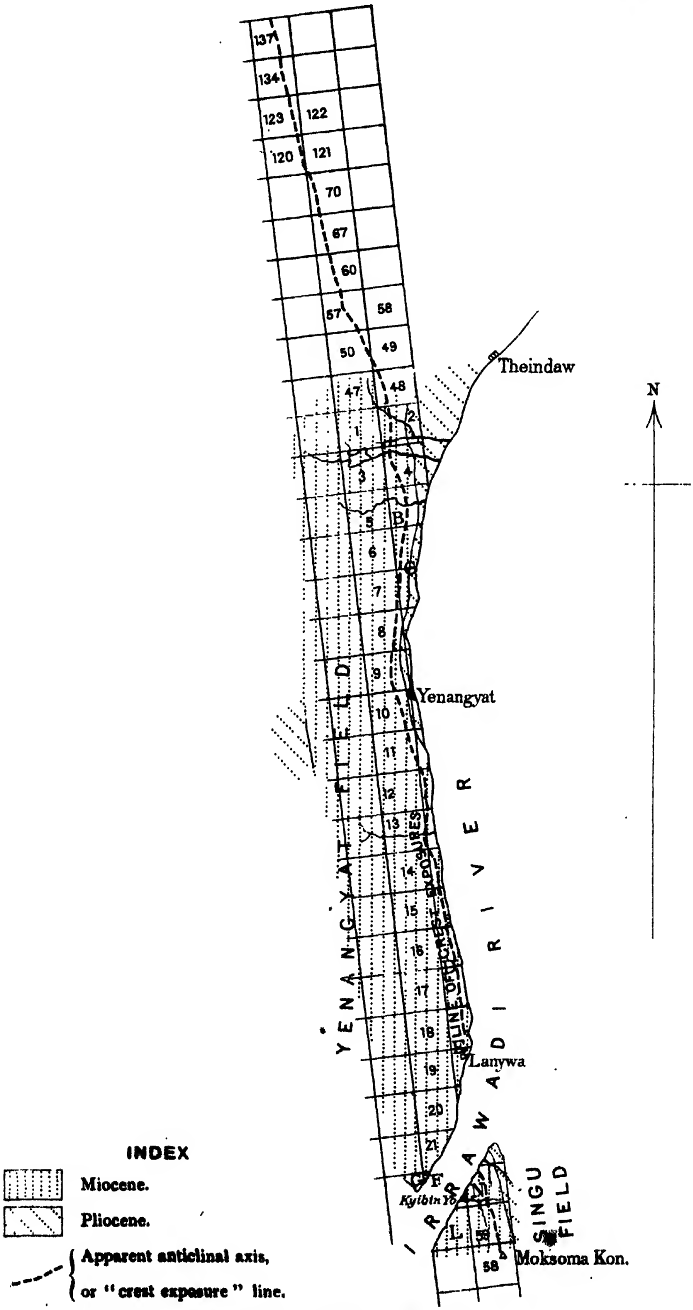
F H Pascoe Photo

Bemrose Collo, Derby

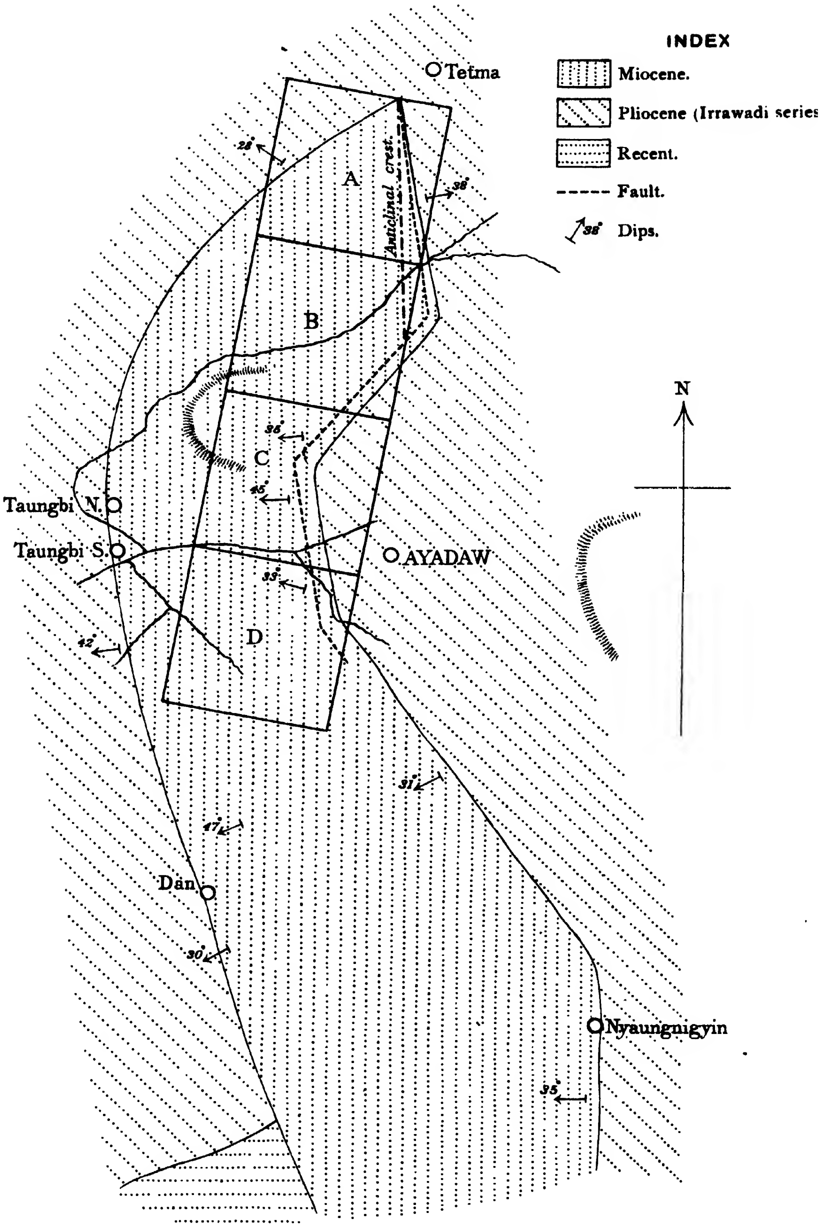
F H Pascoe Phot

Penrose Col Repro

SYNCLINAL FOLD BETWEEN THE KABAT ANTICLINE AND THE SECOND ANTICLINE CHANG MA NEAR KABAT



SKETCH MAP OF YENANGYAT—SINGU ANTICLINE, UPPER BURMA.



MAP OF THE NORTHERN PORTION OF THE GWEGYO ANTICLINE.
MYINGYAN DISTRICT, UPPER BURMA.

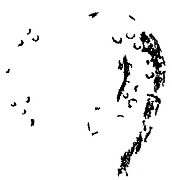
Fig 1 SECTION OF THE ANTICLINAL CREST NEAR AYADAW MYINGYAN DISTRICT UPPER BURMA

Fig 2 CLIFFS OF SOFT PLIOCENE SAND ROCK ON THE BANK OF THE IRRAWADI NEAR YENANGYAUNG SHOWING THE CHARACTERISTIC FORM OF WEATHERING

1

1a

4



3

3a

3b

Drawn by F Vredenburg

Breynia multituberculata n sp